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AVIATION AND AERONAUTICAL ENGINEERING

The New Army Airship A-4 at Its Trials

VOLUME VI
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SPECIAL FEATURES

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COURSE IN AERODYNAMICS AND AIRPLANE DESIGN
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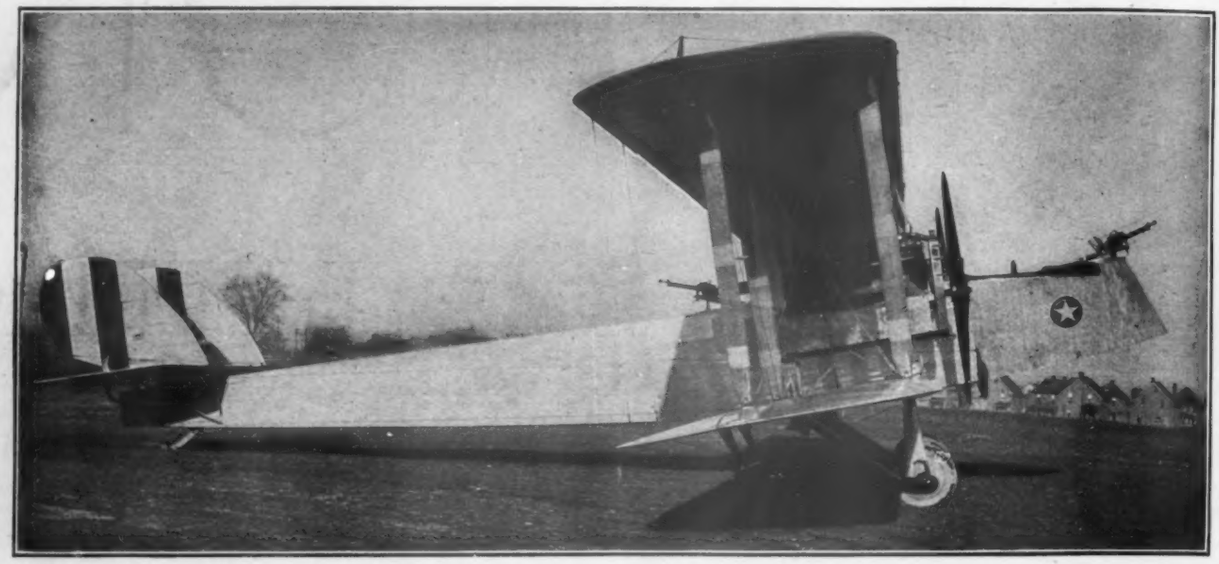

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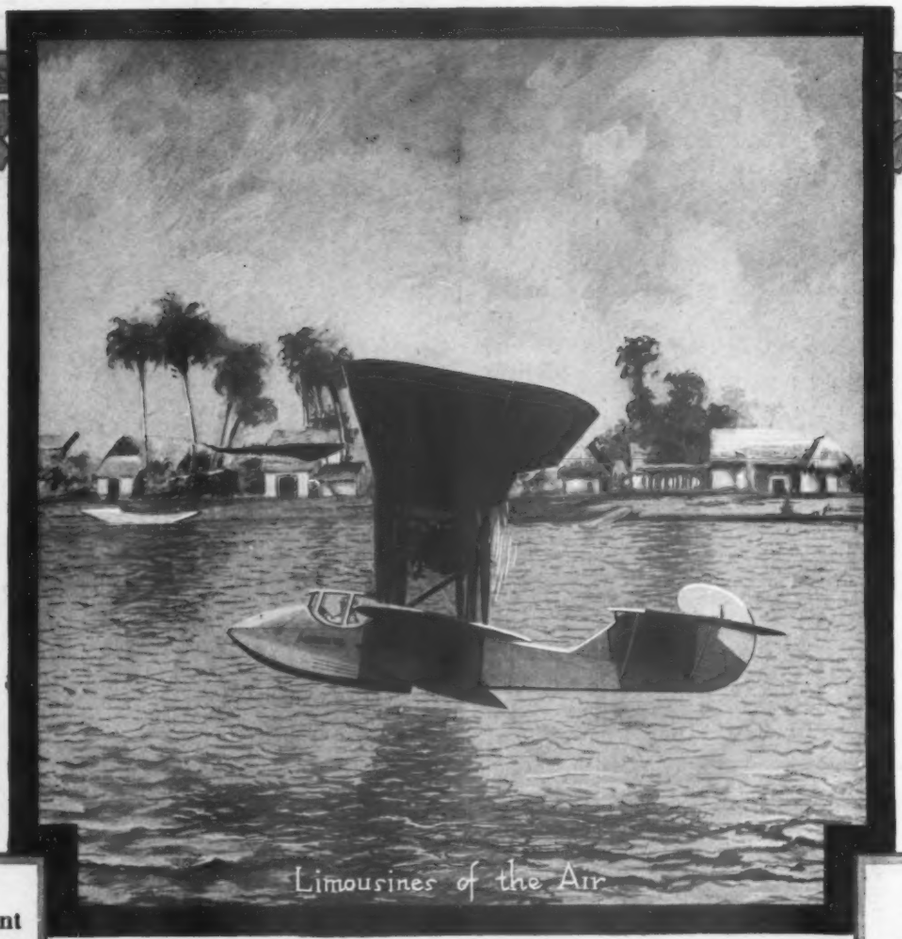

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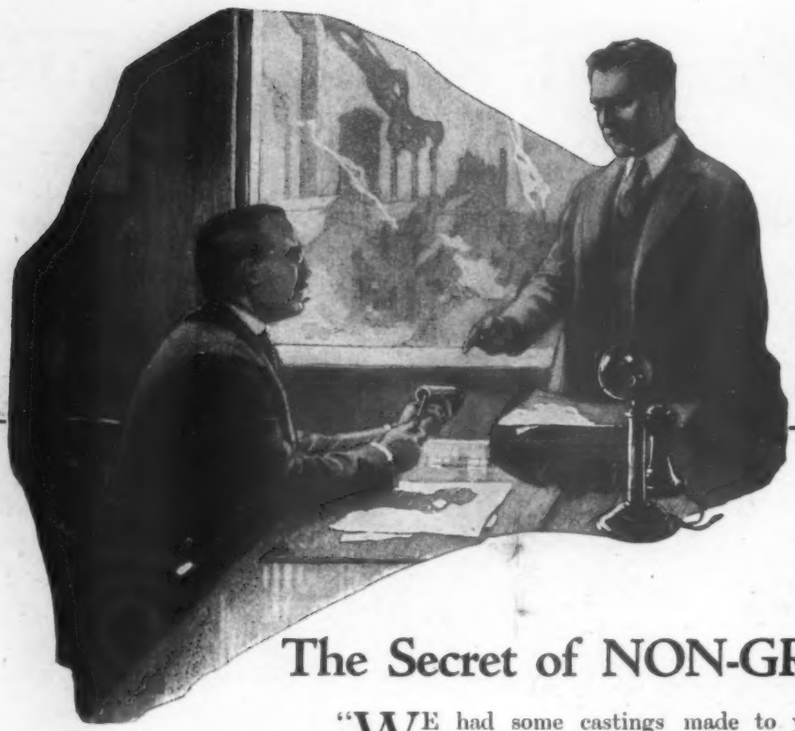

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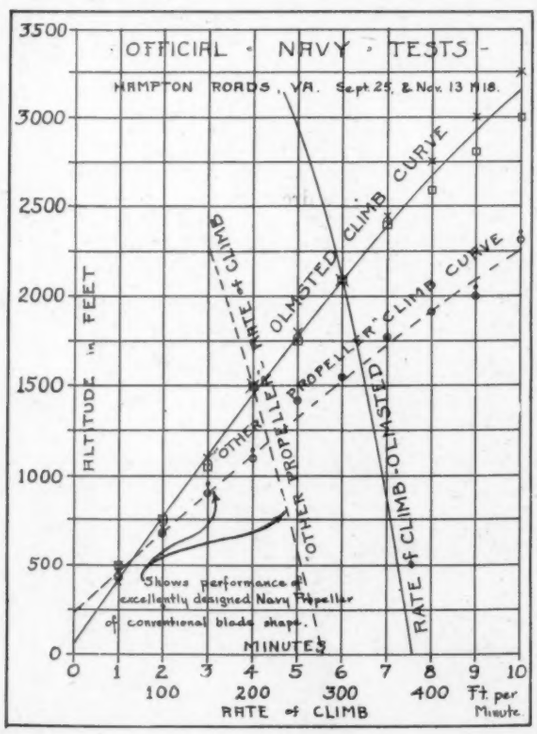

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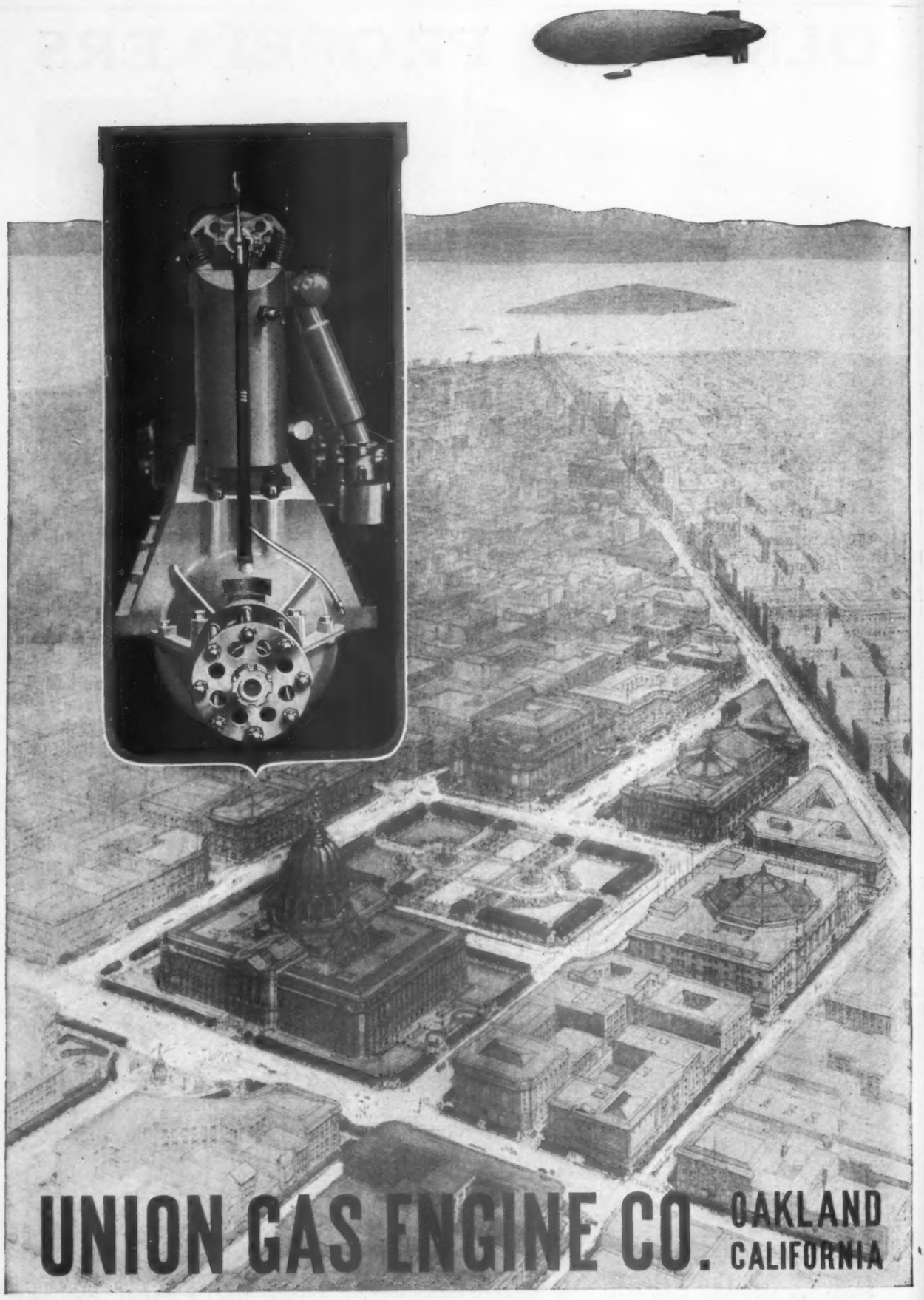
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JUNE 1, 1919

AVIATION AND AERONAUTICAL ENGINEERING

VOL. VI. NO. 9

Member of the Audit Bureau of Circulations

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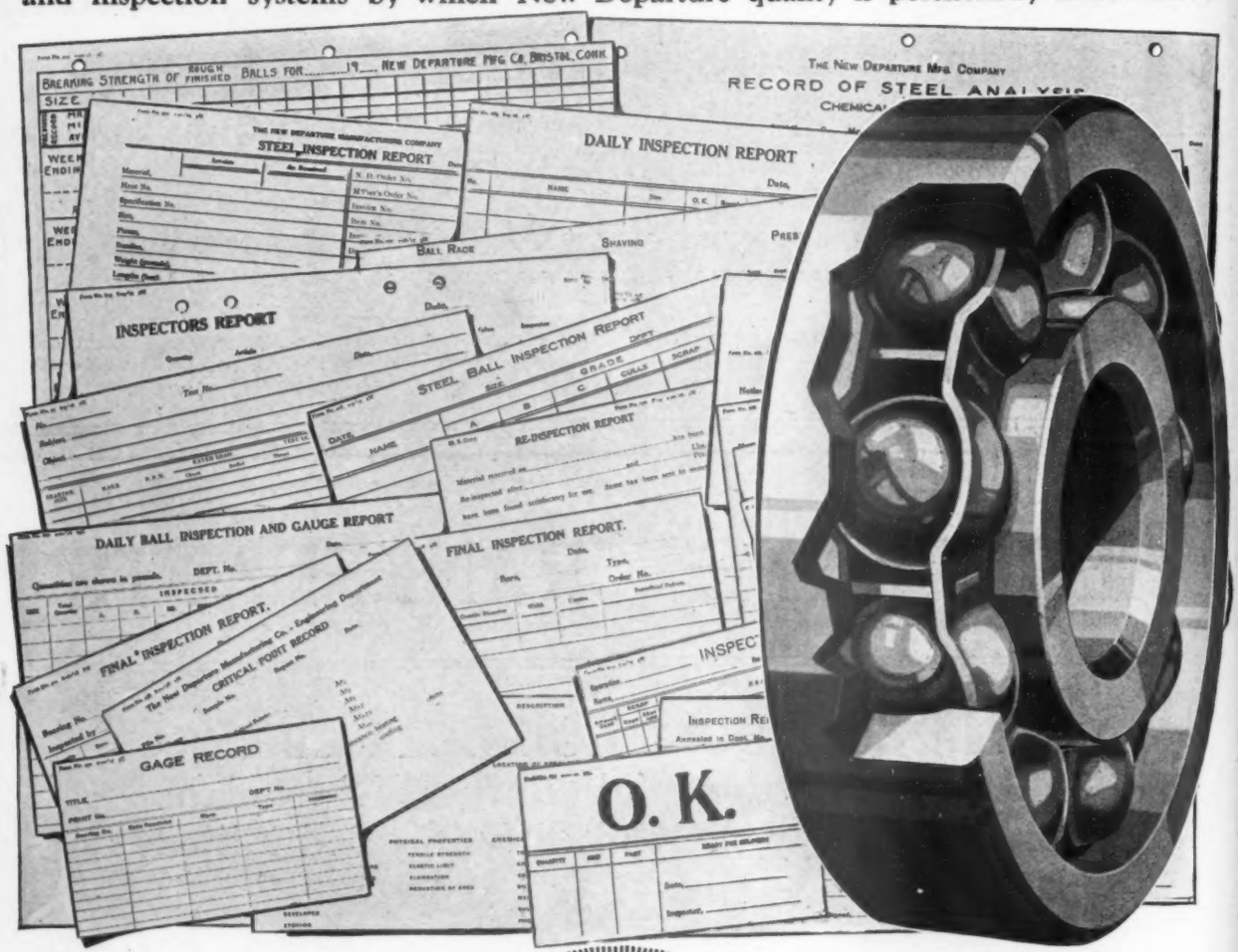
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BUSINESS MANAGER

Vol. VI | June 1, 1919 | No. 9

THE brilliant success which attended the progress of the NC Seaplane Division 1 in its flight to the Azores, and which was marred only in part by the fog, is a lasting monument to the professional skill of our naval aviators as well as to the worth of American seaplane construction.

While Commander Read carried off the laurels for sheer flying performance by making a 1,200-mile non-stop flight from Trepassey to Horta, Commander Towers' successful sailing of his disabled seaplane for two days in heavy seas and storms is an achievement that deserves a place of its own in the annals of aviation. This surface cruise of 200 miles brilliantly shows up the seaworthiness of the large boat-type seaplane, originated and developed by Glenn H. Curtiss, and its great possibilities for ocean travel, while it sheds a new light on the grit and resourcefulness of the United States Navy.

While Commander Bellinger was less successful in his attempt to reach the Azores with the NC-1, his flight, which ended but 100 miles off the goal, is evidence of the excellence of the Liberty engine, which worked faultlessly on all the three seaplanes.

Hawker and Grieve

The unsuccessful attempt of Harry G. Hawker and Commander Mackenzie Grieve, R. N., to win for Great Britain the blue ribbon of the transatlantic flight is a tale of heroism which will be indelibly inscribed upon the rolls of honor of the British race and of mankind.

To attempt to cross 1900 miles of ocean without alighting in a land machine demands more than ordinary determination and endurance; therefore the news that the two gallant Britons have been rescued after hope had almost dwindled as to their chance of survival will cause universal rejoicing.

The Flight of the C-5

The meteoric career of the United States naval airship C-5 affords a highly instructive object lesson to all those concerned with the development of lighter-than-air craft.

On the one hand, we have the outstanding fact of an American-built and American-manned airship of comparatively small size—180,000 cu. ft.—making under most adverse weather conditions a non-stop cruise of 1,100 miles and reaching its destination according to plan, which demonstrates that the airships of the United States Navy are, within their class, second to none.

On the other hand, the unfortunate loss of the C-5 serves to indicate that the problem of mooring an airship in a wind-swept area has not been fully solved as yet. The three-point ground anchorage for airships, which failed in Newfoundland, answers its purpose under average weather conditions, and has the merit of low cost and ease of assembly. But in a gale this mooring puts the envelope and rigging of a nonrigid to an unduly high strain because the wind impinges upon the airship tangentially instead of co-axially; this gives, furthermore, rise to a lifting component which varies with the strength of the wind and therefore causes longitudinal oscillations. In other words, the airship pitches on its moorings, with the ensuing risk of having the envelope damaged if the wind be strong enough.

Experiments carried out abroad lead to the conclusion that instability on the moorings can best be overcome by the use of mooring masts provided with a canvas cup, to which the airship fastens her nose and then swings freely with the wind. Of course, nonrigids require special reinforcement on the nose, but otherwise this solution appears extremely simple and workable; it has in fact given remarkable results abroad, some ships thus moored having outridden winds of 50 m. p. h. The development of a mooring mast, built in sections so it could be easily transported, assembled and taken down again, therefore seems to demand the immediate attention of airship constructors.

The Air Mail Service

The first annual report on the operation of the air mail service between Washington and New York, which has just been made public by the Post Office Department, is a document of more than passing interest and its perusal is well worth the time of all those interested in the development of commercial aeronautics.

The outstanding features of this report are: that out of a possible 138,310 miles there were flown 128,255 miles, that is, a performance of 92.73 per cent.; that out of 1,263 trips only 55 were not undertaken or failed for various reasons—a default of only 4.4 per cent; that during these twelve months there have been only thirty-seven forced landings; that the six airplanes which entered upon this service a year ago are, with the same engines, still in commission, rendering continuous service; that there has occurred no single fatal accident and only two serious and six light injuries in flying operations; and finally, that the balance sheet of the service shows a net surplus of over $19,000.

The record of the air mail not only bears testimony to the careful and efficient manner in which the service has been operated by Hon. Otto Praeger and his assistants; it also proves beyond dispute that the era of aerial transport has truly arrived.

Development of the NC Seaplanes

The history of the inception and development of the NC seaplanes, with additional information on some of their hitherto unknown constructional features and equipment, has been made public by the Navy Department and is printed herewith in part

The inception of the NC type of seaplane dates from Aug. 27, 1917, when Rear-Admiral David W. Taylor, Chief Constructor of the Navy, suggested in a memorandum to Naval Constructor J. C. Hunsaker, U. S. N., his assistant for aeronautics, the desirability of developing "a big flying boat, or the equivalent, that would be able to keep the sea (not the air) in any weather, and also be able to fly across the Atlantic to avoid difficulties of delivery . . . and whereby the submarine menace could be abated, even if not destroyed, from the air." Attention was called in this memorandum to the fact that the Liberty engine gave good promise of being a success and would therefore furnish a satisfactory power plant for these seaplanes.

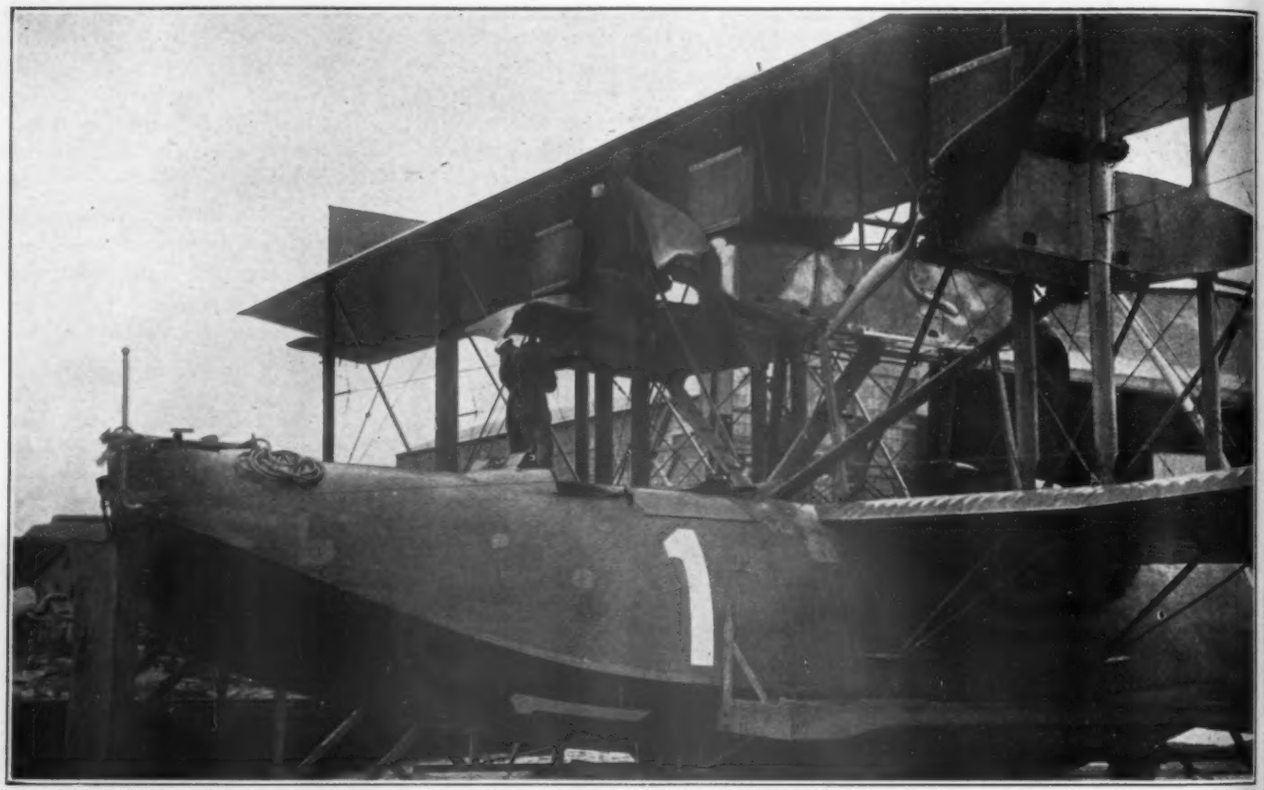
Studies were immediately undertaken by the Aircraft Division, Bureau of Construction and Repair, to apply the Liberty engine to a large seaplane.

Admiral Taylor, after discussion of the problem, directed the preparation of tentative plans to show in a preliminary way the size and nature of a design of large flying boat to combine the maximum of seaworthiness consistent with sufficient endurance to fly across the Atlantic to the anti-submarine operating bases in France and England and to be capable of carrying heavy depth charges and a large battery of machine guns covering every angle of fire. It was anticipated that the boat would be attacked in the air by enemy aircraft.

Preparation of Plans

On Sept. 9, 1917, Glenn H. Curtiss was requested by wire to come to Washington to discuss the proposed design. He arrived the following day, with Engineers W. L. Gilmore and Henry Kleckler. Mr. Curtiss and his engineers went over the preliminary studies prepared in the bureau and proposed that the design have a short hull, with a tail carried high above the water on outriggers. This idea was adopted, in view of the greater seaworthiness, weight-saving, and arcs of fire which such a construction appeared to permit.

Plans were then prepared in the bureau for a boat of this character to be fitted with three engines, and for one to be fitted with five engines. The predicted performance was computed for each boat, from which it appeared that the three-engine boat could be made to satisfy the general requirements of the problem and could be much more quickly built and with smaller risk of failure. Admiral Taylor accordingly directed that the design staff of the bureau be put on the plans of the three-engine type. Investigations were at once undertaken to determine in a preliminary way the construction of wing beams, struts, and the principal structural members, the proportions of wing area, fin, and control surface areas, etc., and the materials to be employed for important parts. The general appearance of the design was worked out, and the procedure established to be followed in making the detail drawings.



FORWARD AND MIDDLE PORTION OF THE NC-1 WITH FOUR LIBERTY ENGINES AND OLMSTED PROPELLERS
Photo Edwin Lewick

Wind Tunnel Tests

A three-foot model of the design was then made exactly to scale and tested by Dr. A. F. Zahm in the wind tunnel of the Washington Navy Yard. From his investigations of the forces on this model, when held in a seventy-mile an hour artificial wind, size and arrangement of tail-surfaces needed to guarantee stability and correct balance in flight were determined. With a machine of the unprecedented size contemplated it was virtually necessary that there should be no doubt on this score, as an accident on the trial flights would set the

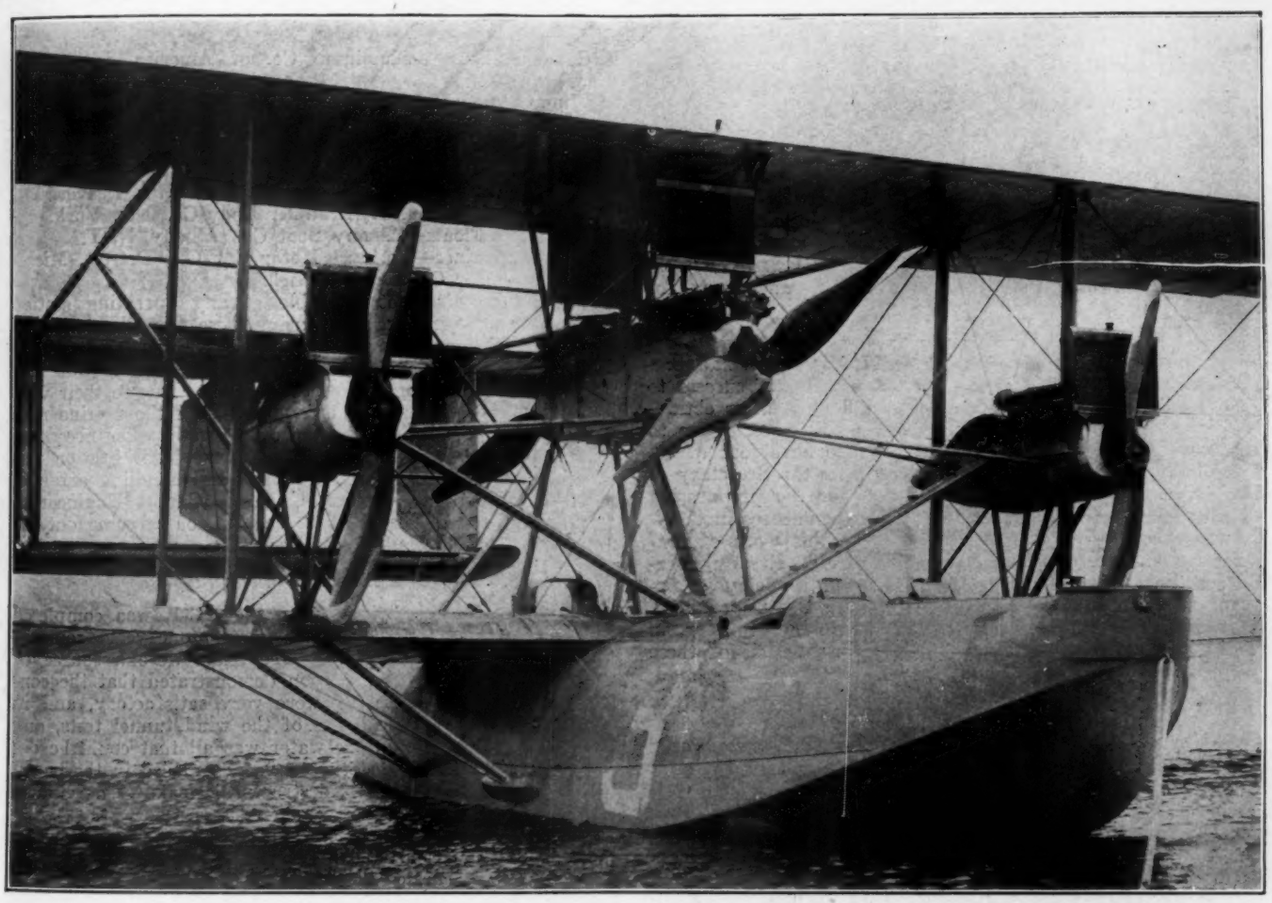
project back many months, besides risking the lives of six to eight men of the crew.

The design being worked upon was of dimensions so far beyond any previous experience in this country or any of the designers in the United States that much unfamiliar territory would have to be covered. In order that the design might be successful, new methods of construction would be required, as otherwise the weight of the design would increase with such rapidity as to make success impracticable. In the state of design information and knowledge as it existed in the United States on that date, this necessity was one of the greatest seriousness, and one which imposed upon the personnel connected with the design a great amount of investigation and experimenting in the working out of the details referred to.

work coming under that bureau, and for this purpose placed in charge, as its field representative, Naval Constructor G. C. Westervelt, U. S. N., whose headquarters were at the plant of the Curtiss Aeroplane and Motor Corp. in Buffalo. Active work on the detail design was begun in Buffalo early in October. Shortly after the commencement Naval Constructor H. C. Richardson, U. S. N., was ordered for temporary duty in connection with the design of the hulls for the boats, and temporarily left his station at the Naval Air Station, Pensacola, Fla., to go to Buffalo.

Hull Design

The hull designed by this officer was of novel form and construction, and embodied directly information obtained



MIDDLE PORTION OF THE NC-3—NOTE THE CHANGE IN THE MOUNTING OF THE WING ENGINES

It soon became apparent that the carrying on to the completion of design work of such dimensions at the Bureau of Construction and Repair in Washington would be impracticable unless the entire facilities of that bureau were devoted to this work. Under the enormous pressure of air matters connected with the war which had developed upon this bureau, in common with the other bureaus of the Navy Department, this was entirely impracticable, and it was decided to arrange with the Curtiss Aeroplane and Motor Corp. of Buffalo, N. Y., to complete the drawings with their own design facilities, and with the contribution by themselves of such ideas of value as might develop under the control and supervision of the bureau.

Contract for Designing

A contract was therefore made with the Curtiss Co. for the performance of this, the drafting and designing work. Under the terms of this contract they were to carry out all the work directed by the Navy Department, furnishing in connection therewith all facilities necessary. The Bureau of Construction and Repair reserved to itself the direction and oversight of all

from his successful seaplane pontoons. The trial later showed that the form adopted represents a very important improvement over the conventional flying boat hulls. The lines were based on model experiments. A series of models of hulls were made up and tested by Naval Constructors McEntee and Richardson in the towing basin at the Washington Navy Yard, and the planing properties of each investigated. The best of the series was adopted for the lines of the flying boat, with confidence that there would be no disappointment in the breaking away from the water. To the working out of the structural details of the boat's hull W. L. Gilmore of the Curtiss Co. contributed much valuable assistance.

This large flying boat was very shortly designated as the NC-1. In this designation the "N" is for the Navy, the "C" for Curtiss, and the "1" is intended to indicate the first of a series of combined Navy-Curtiss designs. As the name would indicate, the design itself is a composite of ideas, these ideas being contributed by many persons, and being chosen and incorporated into the design on the basis of suitability and merit and without any reference to source.

Detail Design Work

In carrying on the actual work of design, the design as a whole was first divided into its main elements. These main elements were designed or approved by the Bureau of Construction and Repair. The details of these main elements were then distributed to the members of the design force at Buffalo working upon them. All ideas, whether of the Curtiss Co. or of the Navy, were pooled, and, as details were worked out, the decision as to the solution to accept was made as a result of discussion.

When this design had progressed sufficiently far to make possible an investigation of its resistance and speed it was found that the power available in the three Liberty engines would be sufficient, and the weight and dimensions were accordingly fixed as the following:

Flying weight, 22,000 lb.; span, 126 ft.; chord, 12 ft.; gap, 13 ft.; length over all, 68 ft. 3½ in.; length of hull, 45 ft.; total wing area, 2,380 sq. ft.; engines, three low compression Liberty type M, developing each 330 hp. at 1590 r.p.m.; weight (empty), 13,000 lb.; speed, 80 m.p.h.

This design is the one which has been worked out and completed.

In the latter part of December the major portion of the engineering and design staff of the Curtiss Aeroplane and Motor Corp. was taken over by the Curtiss Engineering Corp. at Garden City, N. Y., and was transferred there, taking with them the work in connection with the NC-1 design. At that plant the drawings were completed and arrangements for building made.

Authorization

By the early part of December, 1917, the design had progressed far enough and gave sufficient promise of success to justify the Bureau of Construction and Repair, after obtaining concurrence of the Bureau of Steam Engineering as to the power plant, in requesting authority to have four of the type built. This authority was received from the Secretary of the Navy, and instructions were issued for the preparation of a requisition for the covering of the expenditures involved. It was to be feared that the throwing of this work of construction upon the airplane manufacturers, already overburdened with other demands, would result in delaying airplane work already in progress for the Navy Department. This apprehension was expressed in the following letter, in which authority was extended for the construction of these large flying boats:

NAVY DEPARTMENT
Washington, D. C., Dec. 21, 1917.

To Bureau of Construction and Repair and Bureau of Steam Engineering. Subject: Three-Engine Flying Boat Proposed.

1. The bureaus are directed to prepare a requisition as recommended in their joint letter of Dec. 7, 1917.

2. The construction of these seaplanes shall in no way interfere with the production of aircraft to meet the program already laid down, nor with the development and construction of special types of aircraft as recommended by commander naval aviation forces abroad.

JOSEPHUS DANIELS.

Contracts for Construction

A contract was thereupon made with the Curtiss Engineering Corp. for the building of four flying boats of the NC type. Due to the large size of these boats, and to the many novel features of construction involved, it was impossible to estimate with any degree of accuracy the probable cost, and, accordingly, the contract awarded the Curtiss Co. was on the basis of cost of work plus a percentage for profit. This required the placing of this work under the close supervision of the department, and this supervision through the building of these flying boats was exercised for the Bureau of Construction and Repair by Naval Constructor C. C. Westervelt.

The plant of the Curtiss Engineering Corp. at Garden City, N. Y., was of insufficient size for the building of flying boats of the dimensions of the NC-1. It was accordingly necessary for the Navy Department to authorize the building, at its own expense, of a building attached to this plant of sufficient size for the complete assembly of two of these flying boats at one time. In addition, as the ordinary facilities of the Curtiss Co. were such that it was certain that the attempt of that organization to carry out in complete detail the entire construction of these flying boats would be productive of most serious delays in completion, it was decided to build them on the assembly basis.

That is to say, the various elements would be built by various manufacturers building a product of somewhat similar nature, or one requiring workmen of similar qualifications to those ordinarily employed for work of the nature of that in contemplation. These different elements would be shipped to Garden City, to be there assembled into the completed flying boats. As a result of this decision, different parts were built at the following places:

Boat Hulls—Curtiss Engineering Corp., Garden City, N. Y.; Lawley & Sons Boat Co., Boston, Mass.; Herreshoff Co., Bristol, R. I.

Tail Beams—Pigeon-Fraser Hollow Spar Co., Boston, Mass.

Gasoline Tanks—Aluminum Co. of America, Pittsburgh, Pa.

Wings, Control Surfaces and Struts—Locke Body Co., New York.

Nacelles, Major Details Gasoline System, and All Wiring—Curtiss Co., Garden City, N. Y.

Metal Fitting—Unger Bros., Newark, N. J.; Beaver Machine Co., Newark, N. J.; Brewster Body Co., New York.

Wing Tip Floats—Albany Boat Co., Albany, N. Y.

Liberty Engines—Packard Motor Car Co., Detroit, Mich.; Ford Motor Car Co., Detroit, Mich.

There were also not available at any operating station hangars of sufficient size for housing these flying boats. Construction was arranged for by the Navy Department at the Rockaway Beach Naval Air Station for a building of sufficient size for housing two of these boats. Due to their very large size, special handling arrangements of the marine railway type for getting into and out of the water when necessary were provided. The Rockaway Beach Naval Air Station was chosen for the location of the hangar and handling arrangements on account of its nearness to the Curtiss Engineering Corp. plant and of its excellent location for carrying out the flying tests which would be necessary.

Test Flights of the NC-1

The first of these flying boats, the NC-1, was completed and flown Oct. 4, 1918, or approximately one year from the commencement of the design. The trials were a source of great satisfaction, as it was soon demonstrated that the control and balance in the air were very satisfactory, and in accordance with the prediction of the wind tunnel tests, and that the performance on the water was all that could be desired and entirely justified the confidence placed in the model tests in the towing basin. No structural weakness developed, and the speed came out as predicted. In short, this flying boat, designed from theoretical and model experimental data, combined with the practical experience of a half dozen or more people, performed in every way so close to her designed characteristics as completely to justify the methods of the naval architect as here applied in the design of a flying machine.

As flying tests on the first boat were continued, many changes were tried with a view to improve the original design, and as these were found advantageous were incorporated on this and on the other three boats then building.

Change to High-Compression Liberty

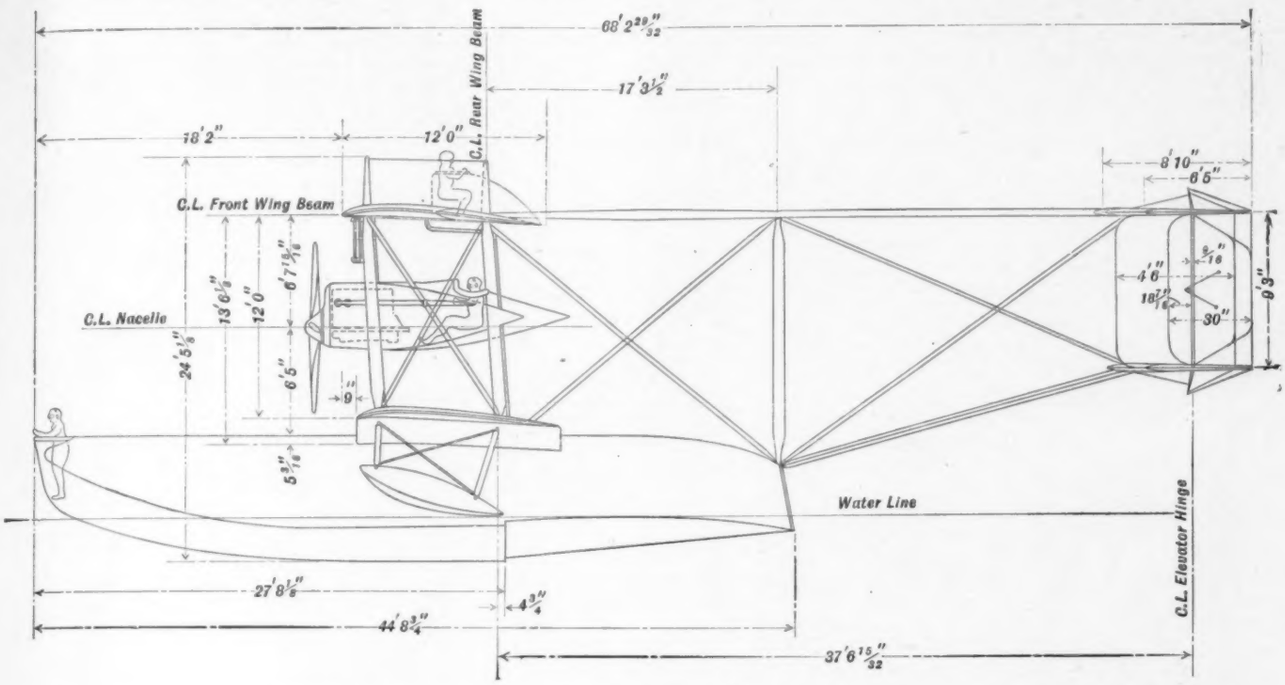
The Bureau of Steam Engineering, at this stage, was able materially to improve the performance of the boat by the application of new propellers designed in that bureau. The NC-1 was originally fitted with standard navy low-compression Liberty engines, which were found to be entirely satisfactory, but during the period that the NC-1 was being tested with these engines the Bureau of Steam Engineering at its experimental laboratory at the Washington Navy Yard perfected carburetor adjustments on the high-compression Liberty engines which materially improved its economy.

Since the high-compression engine gave greater power than the low-compression engine, such engines replaced the original installation on the NC-1. With the new propellers and the new engines, the boat got out of the water and flew easily with a total weight of 24,700 lb. The designed load was 22,000.

Besides providing propellers and engines for the boat, the

Bureau of Steam Engineering supplied a remarkably efficient electric self-starter to each engine. This type of self-starter weighed only thirty-five pounds, and by means of this improvement it was possible for the pilot to start any engine without leaving his seat. It is believed that this constitutes the first application of an electric self-starter to the Liberty engine.

The month of November, 1918, was spent in thoroughly trying out the NC-1. Among other flights a round trip from Rockaway, N. Y., to Washington, via the entrance to Chesapeake Bay, was made with nine persons on board. On Nov. 25 the NC-1 broke the world's record for passenger carrying, having on board in the air fifty-one persons. One of these was a stowaway, who had concealed himself in the interior of the hull for over an hour prior to the starting of the flight, and is probably the first man to deliberately stow himself away on an airplane in order to make a voyage. On these flights Naval Constructor Richardson was in charge and was one of the pilots.



SIDE ELEVATION OF THE NC-1, AS ORIGINALLY CONSTRUCTED WITH THREE LIBERTY ENGINES AND WING GUN-TURRET

Four-Engine Installations

After making various minor improvements, it was concluded that the maximum which could be obtained from three Liberty engines had been reached, and no further improvements in performance could be expected until geared engines became available. It was believed that the geared engines were still in an experimental stage. It was apparent, however, that the flying part of the craft could sustain a greater load if more power were available, and it was accordingly decided to add a fourth engine, making a total of 1600 hp.

The second boat completed, designated as NC-2, was therefore fitted with four Liberty engines, arranged as two pairs of tandems, and on its trials in March, 1919, successfully flew with a total weight of 28,000 lb. The addition of the fourth engine, which increased the dead weight of the boat by about 1,500 lb., permitted about 3,300 lb. of extra weight to be carried, or a net gain of 1,800 lb.

The NC-3 and NC-4 were completed in April, 1919, and were likewise fitted with four high-compression Liberty engines, but with a somewhat different arrangement. In these two boats two engines were arranged on the central line as a tandem pair driving a tractor and a pusher propeller, respectively, with the other two engines mounted on the wings as tractors, as were the wing engines on the NC-1. In these boats a further change was made by omitting the centre nacelle and placing the pilots in a cockpit in the hull.*

These boats, as completed and equipped, with all instruments, cooling water and fixed accessories, weigh 15,874 lb., and when fully equipped with crew, radio, ice and water, spare parts, and with fuel and oil for a flight of 1,400 sea miles, weigh 28,000. The useful load carried is, therefore, 12,126 lb., or over 43 per cent. With the full load of 28,000 lb., the boats make a speed of 85 m.p.h. and leave the water easily. At the average loading of 24,000 lb. the full speed is 95 m.p.h.

Hull Construction

The hull or boat proper is 45 ft. long by 10 ft. beam. The bottom is a double plank Vee, with a single step somewhat similar in form to the standard navy pontoon for smaller seaplanes. Five bulkheads divide the hull into six water-tight compartments, with water-tight doors in a wing passage for access. The forward compartment has a cockpit for the lookout and navigator. In the next compartment are seated side by side the principal pilot, or aviator, and his assistant. Next comes a compartment for the members of the crew off watch to rest or sleep. After this there are two compartments containing the gasoline tanks (where a mechanician is in attendance) and finally a space for the radio man and his apparatus. The minimum crew consists of five men, but normally a relief crew would be carried in addition.

The hull is designed to have an easy flaring bow, so that it can be driven through a seaway to get up the speed necessary to take the air, and a strong Vee bottom to cushion the shock of landing on the water. The combination of great strength to stand rough water, with the lightweight required of anything that flies, was a delicate compromise and it is believed that a remarkable result has been obtained in this design.

The bare hull as completed by the yacht builder and ready

*In the meantime the NC-1 was rebuilt to conform to the engine arrangement which proved successful on the NC-3 and the NC-4. The principal remaining difference between the latter and the NC-1 is that the wing-engine nacelles of the NC-3 and the NC-4 are fitted somewhat below the level of the center engine nacelle, and are streamlined. The bracing of the wing-engines has furthermore been simplified on the Three and the Four, the nacelles being supported on pyramid-like structures of steel tubing (which take the place of the inner engine struts of the NC-1) and are braced to the center engine nacelle by steel tubes.—Editor

for installation of equipment weighs only 2,800 lb., yet the displacement is 28,000 lb., or one-tenth of a pound of boat per pound of displacement. This lightness of construction was attained by a careful selection and distribution of materials. The keel is of Sitka spruce, as is the planking. Longitudinal strength is given by two girders of spruce braced with steel wire. To guarantee watertightness and yet keep the planking thin, there is a layer of muslin set in marine glue between the two plies of planking.

Wing Construction

The wings are of R. A. F. 6 curve and carry in flight a maximum load of 11.7 lb./sq. ft. The structural weight of the wings is 1.2 lb./sq. ft. The total wing area is 2,380 sq. ft.

Wings of this size could not be constructed by the usual method and materials without materially exceeding this figure, and a great amount of research and experiment has been necessary to determine the best disposition of material to adopt.

The main wing spars are hollow spruce boxes. Each rib is a truss designed like a bridge, consisting of continuous cap strips of spruce, corresponding to the upper and lower chords of a bridge truss, tied together by an internal web system of vertical or diagonal pieces of spruce. The ribs are 12 ft. long, but only weigh 26 oz. each. On test these ribs were required to carry a proof load of 450 lb. of sand for 24 hr. without damage.

An interesting detail of the wing construction is the hinged leading edge which incloses the control cables to the ailerons, or wing flaps. This eliminates the air resistance of these cables, but at the same time they are accessible for inspection by merely swinging up the leading edge on its hinges.

The wings are arranged as a biplane with the necessary struts and wires to give girder strength. For lightness the struts are made up as a spruce box, but to decrease resistance this square portion is inclosed in a fairing of stiff fibre. To reduce any tendency of the struts to bow under load, the middle points are connected with a steel cable. The diagonal bracing between the wings is by means of a steel cable in pairs. These cables are arranged to lie one behind the other with a spruce batten between to reduce resistance.

Ailerons are fitted to the upper planes only and project 6 ft. beyond them. Their total area is 265 sq. ft.

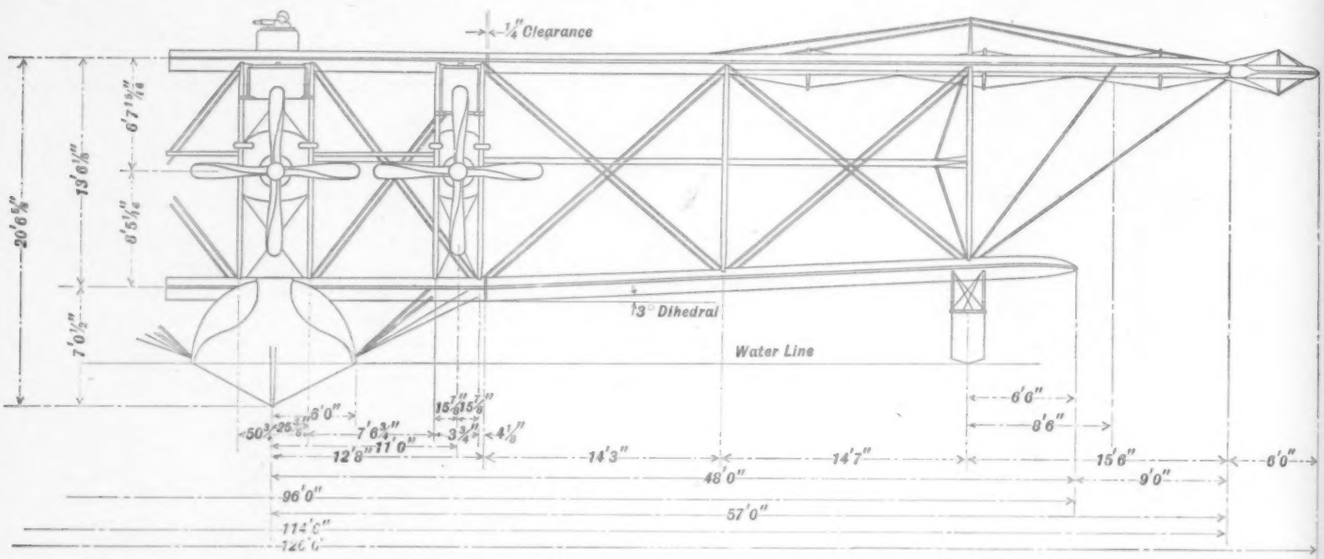
The wing pontoons each weigh 95 lb. and displace 1,800 lb.

The metal fittings where struts and wires are fastened to the wings presented a serious problem. The forces to be taken care of were so large that it was necessary to abandon the usual methods of the airplane builder and adopt those of the bridge designer. All forces, acting at a joint, pass through a common centre. In this case, as in a pin bridge, the forces are all applied to a large hollow bolt at the centre of the wing beam. In the design of the metal fitting, to reduce the amount of metal needed, it was decided to employ a special alloy steel of 150,000 lb. per sq. in. tensile strength. To increase bearing areas, bolts and pins are made of large diameter but hollow.

Tail Structure

The tail structure is built up in the form of a biplane and is supported by three hollow booms braced by steel cable in such a way as to remain clear of all breaking seas and to permit a machine gun to be fired straight after from the stern compartment without interference. This method of supporting the tail structure, beside embodying several other advantages such as the reduction of frictional resistance of the hull, has resulted in an important saving in weight.

The horizontal stabilizers have a total area of 267.6 sq. ft., and the elevators, 240.1 sq. ft. The total area of the three rudders is 69 sq. ft.



FRONT ELEVATION OF THE NC-1 AS ORIGINALLY CONSTRUCTED

Power Plant

The four high-compression Liberty engines which drive the boat are mounted between the wings, as described before. This arrangement of engines has the advantage of concentrating weights near the centre of the boat so that it can be maneuvered more easily in the air.

A feature that is new in this boat is the use of welded aluminum tanks for gasoline. There are nine 200-gal. tanks made of sheet aluminum with welded seams. Each tank weighs but seventy pounds, or .35 pound per gallon of content, about one-half the weight of the usual sheet steel or copper tank.

Control Arrangement

The steering and control in the air are arranged in principle exactly as in a small airplane, but it was not an easy problem to arrange that this fourteen-ton boat could be handled by one man of only normal strength. To insure easy operation, each control surface was carefully balanced, in accordance with experiments made in a wind tunnel on a model of it. The operating cables were run through ball-bearing pulleys and all avoidable friction eliminated. Finally, the entire craft was so balanced that the centre of gravity of all weights came at the resultant centre of lift of all lifting surfaces and the tail surface so adjusted that the machine would be inherently stable in flight.

As a result the boat will fly herself and will continue on her course without the constant attention of the pilot.

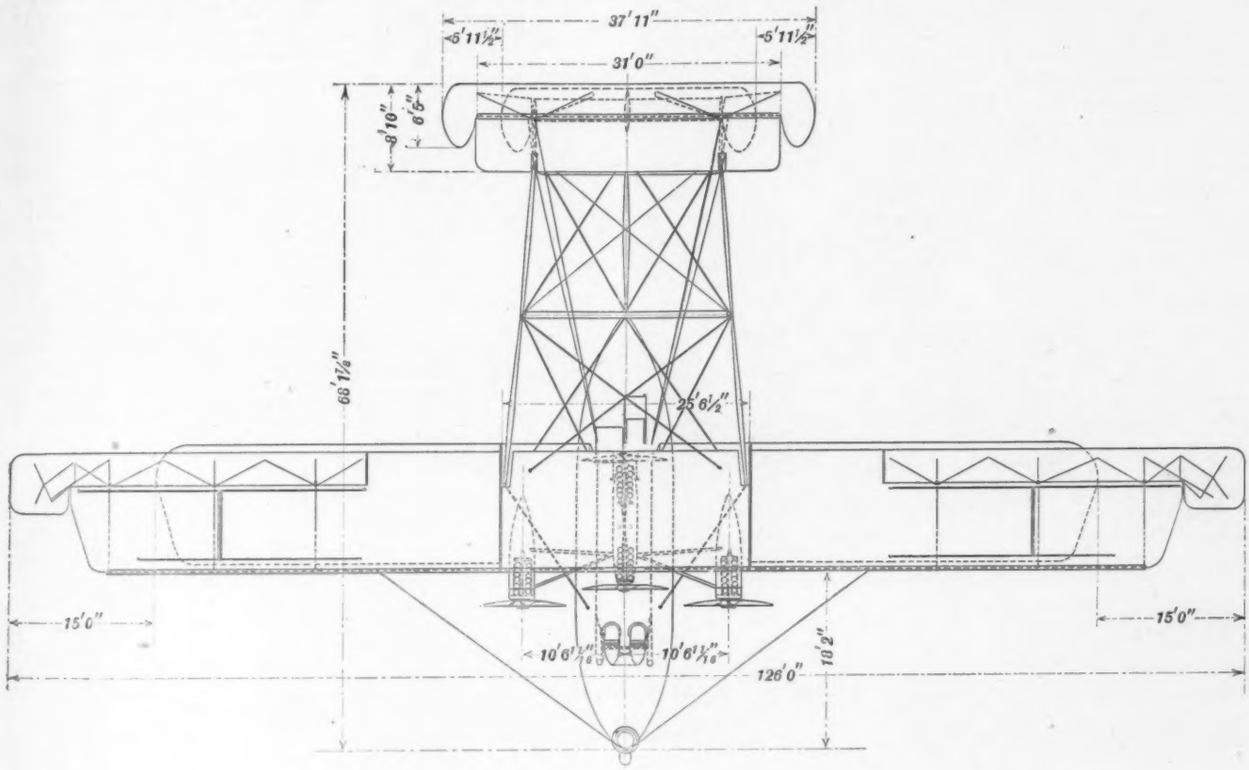
To relieve the pilot of the strain of flying great distances dual control sets are installed, with the pilot and assistant pilot seated abreast.

Radio Telegraph

The radio on the NC seaplanes involves two transmitters. One is a ½ kw. spark transmitter, the main element of which is a streamline generator and accessory apparatus, which is given by an air propeller and is mounted on the deck of the

boat aft. This set weighs only 45 lb., but is used for the regular telegraph communication between the seaplanes and stations up to a distance of 250 nautical miles. Since this set is driven by a propeller, it can only be used while seaplanes are in flight. The antenna used for this set is a single trailing wire leading from the tail of the boat for a distance of 250 ft. down and to the rear. A streamline lead weight holds the lower end of this wire down.

With this transmitter it is possible for the commanding officer to send messages from time to time regarding the progress of the flight, to be retransmitted by the nearest shore station to the Navy Department. Also communication can be held with destroyers or other craft and radio compass signals or other information requested.



PLAN VIEW OF THE NC-CLASS AS FITTED WITH FOUR LIBERTY ENGINES

Radio Telephone

The other transmitter is a combined telephone and telegraph transmitter, and operates on a small 12-volt storage battery. It is used on an antenna consisting of wires permanently stretched on the skid fins on the upper planes so that it may be used while the seaplane is in flight or on the water.

It is this set which is used for telephoning between the planes, arrangement being made so that either the radio operators or the commanding officers themselves may communicate directly by telephone while the planes are in flight. Such interplane telephoning may be carried on up to a distance of twenty miles. While on the water this set may be used for telegraphing or telephoning a distance of about thirty miles.

A special feature of the telephone sets is the anti-noise microphone, which is so constructed that the engine noises are not heard. This is accomplished by having the back of the microphone open. The exterior sound waves strike the back as hard as the face of the diaphragm, and therefore the effect is neutral. The voice waves strike only the face of the diaphragm, and even though the operator cannot hear his own voice, the radio sets receive enough effect to modulate the transmitted wave.

This single item has been the deciding factor in success or failure in long distance transmission by telephone by airplanes. It is easy enough for short distances to get communication with an ordinary microphone, but for long ranges it is impossible without the anti-noise transmitter.

One of the most important of the radio installations on these seaplanes is the radio compass. This consists of a set of revolving coils mounted in the tail of the machine, on which are mounted many turns of enameled copper wire. The radio waves are picked up on these coils by revolving the coils until the radio signals obtained on two methods of connection are of the same strength.

The operator then knows the direction of the incoming waves. By then reading the position of a pointer on a scale on the coils, the bearing of the transmitting radio station is determined. This bearing is then communicated by the radio operator to the navigating officer by means of the inter-communicating telephone, which consists of telephone receivers built into the helmets, and the same type of microphone used by the operator.

Using the same inter-communicating telephone system, the navigator can telephone to the pilots, giving them the proper direction in which to steer the plane. He may inquire of the engine room regarding the condition of the engines, or he may hold radio telephone conversation with the navigating officer on one of the other planes.

In other words, the inter-communicating telephone makes possible constant communication between all members of the crews in spite of the terrific noise caused by the engine and the wind rush, and in spite of the fact that they are located in separate parts of the seaplane. In addition to this the radio telephone makes it possible for the commanding officer and navigators to talk directly with each other, although their seaplanes may be flying at a distance of 20 miles apart.

The radio compass signals may be received from a destroyer at a distance of 75 miles, or from large land stations at a distance of 600 miles.

The regular receiving apparatus on the seaplanes will permit of reception from land stations of high power at distances of several thousand miles.

The main striking fact regarding this radio equipment is that, completely installed, it weighs only 200 lb.

In addition to the usual aircraft instruments, the NC seaplanes have been equipped with three special instruments which answer the purpose of facilitating oversea navigation where points of repair are scarce. They are an aerial sextant, a drift and speed indicator, and a course and distance indicator.

The main feature of the aerial sextant, known as the Byrd sextant, invented by Lieut.-Comdr. H. L. Byrd, U. S. N., is that a bubble in a tube takes the place of the sea horizon and observations. A specially constructed lens is used in sighting the bubble, which is reflected in a mirror. The sun is reflected in another mirror. The observer brings the sun tangent to a line at the same time he brings the bubble tangent to the line. That gives the altitude of the sun. This is of especial value, as the aviator is often above the clouds, and even when flying at low altitudes the horizon is too dim to be seen clearly. With this new aerial sextant the curvature of the earth does not have to be taken into consideration in calculating position. The bubble is lighted at night, so that night observations may be taken.

Another great problem of the navigator is the calculation of the speed and direction of the wind, both day and night. In spite of the reliability of the compass, it can only give the course upon which the craft heads, and in determining the true course proper allowance must be made for the sidewise drift caused by the wind.

To overcome this difficulty bombs have been invented which ignite upon striking the surface of the water and give a dense smoke and bright light for ten minutes. An instrument is used in conjunction with this bomb which enables the navigator to determine the velocity and direction of the wind by sighting on the smoke in the daytime and the lights at night. This instrument, called the speed and drift indicator, has proved successful.

When the navigator has found the speed and direction of the wind, he must then be able to calculate the course to allow for this wind. To do this an instrument has been designed to solve the triangle of forces, thus doing away with cumbersome mathematical calculations. This is very important, because in aerial navigation positions must be determined very quickly. The navigator sits down to work out his "sights," to fix his position, and will be far from his calculated position unless he works out his calculations very rapidly, which these instruments enable him to do.

New methods of astronomical calculations also have been devised which enable the navigator to make his calculations in a fifth of the time that was formerly necessary. A projection chart of the Atlantic Ocean has been specially constructed for this purpose. This chart, a new invention, does away with difficult mathematical calculations, enabling the aviator to determine his position in a few minutes.

NC-3 and NC-4 Reach Azores

The NC Seaplane Division 1, under command of Comdr. John H. Towers, U. S. N., started on its trans-Atlantic flight on May 16, at Trepassey, N. F. The division was at full strength, for the NC-4 (Commander Read), which had put in at Chatham naval air station for engine repairs while bound for Newfoundland, had joined her sister ships in time for the start. The NC-4 flew on May 14 from Chatham to Halifax, N. S., 300 sea miles (345 land miles), in 3 hr. 51 min., and on May 15 from Halifax to Trepassey, 460 sea miles (529 land miles), in 6 hr. 20 min.

The NC-1 (Commander Bellinger), NC-3 (Commander Towers) and NC-4 (Commander Read) took off at Trepassey at 9.36 p. m., 10.03 p. m., and 10.07 p. m., Greenwich meridian time, respectively, flying in formation, and being guided on their course by the smoke and searchlights from the destroyers which were stationed at 50-mile intervals all the way to the Azores. Throughout the night the weather was clear, but by daybreak fog came up and separated the three seaplanes. The NC-4 then drew ahead and reached, without any incident, Horta, on the island of Fayal, where it landed at 1.08 p. m., G. M. T., having covered 1200 sea miles (1380 land miles) in 15 hr. 5 min.

The NC-3 and NC-1 were not so fortunate, however. The NC-1 got into the thick of the fog and, having lost her bearings, was compelled to make a landing, which was successfully carried out at 1.10 p. m., Saturday, despite a rough and choppy sea and a strong wind. At 6 p. m. the NC-1 sighted the steamsip Ionia and taxied toward her; a boat was lowered from the ship and the crew of the seaplane was taken on board. Attempts were made to salvage the NC-4, but the tow lines broke in the heavy sea, so that the seaplane had to be abandoned and eventually sank. But for the fog the NC-1 could have reached Horta, for the engines worked splendidly throughout the trip.

The NC-3, which had flown at a higher level than her two consorts on account of the failure of the lights on the instrument board and low-lying clouds, which made it necessary to have the heavenly bodies for reference, was somewhat thrown off her course by the high velocity of the upper winds and ran into heavy rain squalls on Saturday morning. With only 2 hr. fuel left, she made a landing at 11.30 a. m., some 100 miles from Horta, in order to make observations, but the heavy sea slightly damaged the hull and seriously damaged the center forward engine struts, which made it impossible to leave the water. Commander Towers thereupon decided to make for the nearest shore, and succeeded in reaching Ponta Delgada at 5.50 p. m., G. M. T., on May 19, after having outridden a gale which lasted two days. The NC-3 suffered severely in the storm, losing both wing pontoons, but nevertheless sailed the total distance of 205 miles under her own power. Upon examination, at Ponta Delgada, it was found that the NC-3 was unfit for the second leg of the flight, and would have to be rebuilt in part.

On May 20 the NC-4 proceeded on her voyage, flying from Horta to Ponta Delgada, a distance of 115 sea miles (172 land miles), in 1 hr. 44 min. Bad weather then set in, and at the date of writing the NC-4 is still at Ponta Delgada awaiting favorable atmospheric conditions to complete her trans-Atlantic flight.

Hawker and Grieve

Harry G. Hawker and Lieut.-Comdr. Mackenzie Grieve, R. N., pilot and navigator, respectively, of the Sopwith biplane, entered for the Daily Mail trans-Atlantic flight competition, took off at 5.51 p. m., G. M. T., May 18, at Mount Pearl aerodrome, near St. Johns, N. F., in their attempt to reach Ireland in a non-stop flight of 1925 sea miles. After nothing had been heard from them for several days it was feared that the intrepid fliers had been lost at sea.

Altogether the weather at Newfoundland was quite favorable for the attempt, with a cloudless sky and a moderate favoring breeze, but later weather forecasts indicated anything but favorable conditions toward the Irish coast, a marked depression, with rain and fog being reported for those quarters. It was believed that the two gallant Britishers were eventually blown out of their course and, having run out of fuel, were compelled to alight on the sea; in this case they had but the slightest chance of being rescued, for their machine had no pontoons or even any temporary floating arrangement, only a small boat carried on the top of the fuselage, and unsinkable suits having been provided for their safety.

However, on May 25, the Danish steamer Mary reported to have "saved all hands of Sopwith airplane," and the following day Hawker and Grieve were landed at Thurso, Scotland. According to a statement made by Hawker, he was compelled to alight on the sea some 800 miles off Ireland on account of radiator trouble, and was picked up by the Danish steamer after an hour and a half.

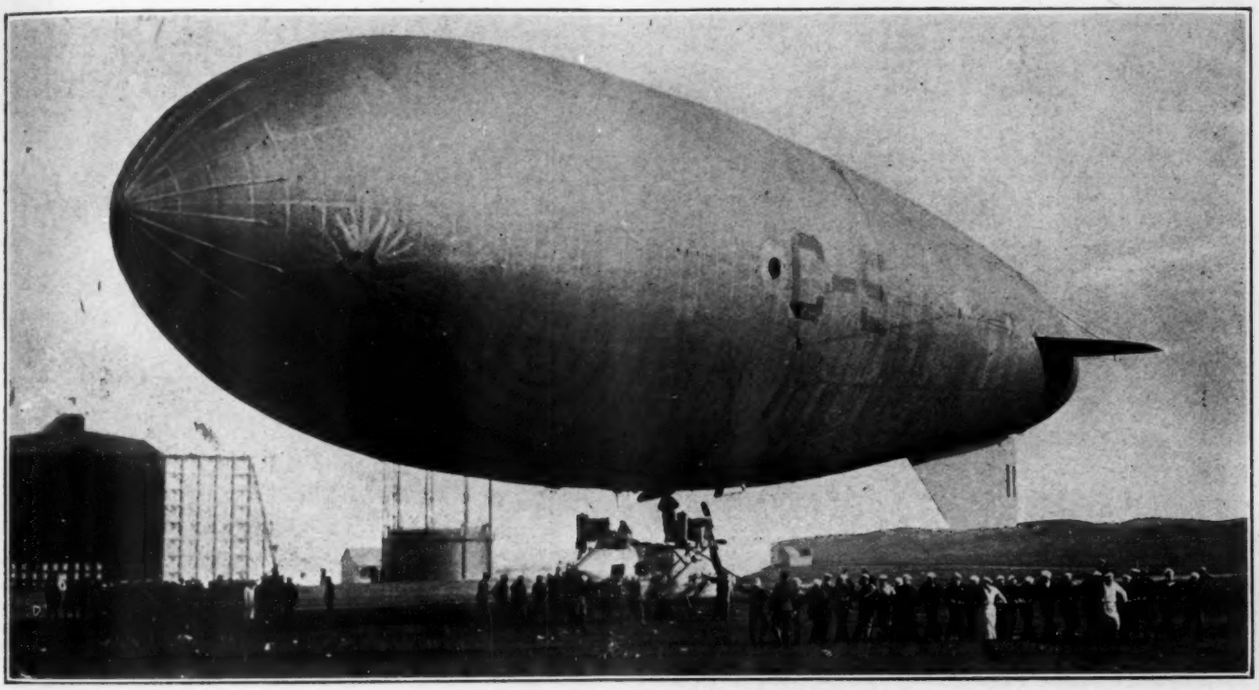
The Sopwith trans-Atlantic biplane was 46 ft. 6 in. in span and 31 ft. in overall length. It was fitted with a 12-cyl. "Eagle" Rolls-Royce engine, developing 375 hp. and driving a geared-down two-bladed propeller; the fuel tanks held 400 gal, of gasoline, estimated to last in still air 25 hr. The high speed was 105 m.p.h. and the flying weight, fully loaded, 6300 lb.

Another entrant for the Daily Mail competition, the Martinsyde biplane (Capt. F. P. Raynham, pilot, and Capt. C. W. F. Morgan, navigator), attempted to follow the Sopwith shortly after its start, but in taking off the landing gear struck a ridge lying athwart the course and collapsed, badly damaging the machine in the ensuing crash. Captain Raynham suffered minor bruises, but Captain Morgan was badly injured and will probably be unable to navigate the Martinsyde after it has been rebuilt for a second attempt.

Naval Airship C-5 Makes 1100-Mile Flight

The United States naval airship C-5, Lieut.-Comdr. E. W. Coil, U. S. N., commander, made on May 14-15 a non-stop flight of 970 nautical miles (1115 Sta. miles), from Montauk naval air station to St. Johns, N. F., in 25 hr. 40 min.

According to a statement issued by the Navy Department, the cruise was undertaken for the purpose of testing the practical radius of action of this class of airships, as well as their ability to operate under varying weather conditions; the outcome of this flight would determine the advisability of having the C-5 attempt to cross the Atlantic under her own power.



NAVAL AIRSHIP C-5 STARTING ON HER 1100-MILE CRUISE
(C) *Underwood and Underwood*

The Voyage

The 1100-mile cruise of the C-5 fully vindicated the expectations of the Navy department with regard to the cruising radius and air worthiness of this airship. Taking off at 8 a. m. at Montauk naval air station with a moderate breeze on her tail, which increased as she headed seaward, the C-5 shaped her course by way of Cape Cod, Cape Sable and Cape Breton to St. Johns, N. F. Throughout the day the weather was fair, and after nightfall the full moon facilitated progress until 10.30 p. m., when the sky became overcast and the winds became shifty, making steering exceedingly difficult. For the greater part of the night the C-5 swayed and tossed in the gale, rolling at times so heavily that the engines chocked and temporarily stopped. Intense cold added to the discomfort of the crew, but men and machinery stood up splendidly under the severe ordeal. When morning broke the storm subsided, but fog came up, and the airship lost her bearings. After some unsuccessful attempts to determine her position by directional wireless, while the ship was cruising over Newfoundland, the C-5 succeeded in communicating with U. S. S. Chicago by radiophone, and made at 10.45 a. m. a safe landing at Pleasantville, near St. Johns. An American handling crew which was awaiting her arrival then moored the ship to a three-point anchorage which had been prepared for the emergency.

The crew of the C-5 was made up of Lieut. J. B. Lawrence, first assistant pilot; Lieut. (j. g.) E. O. Campbell, coxswain; Ensign M. H. Easterly, radio operator, and Chief Machinists Mates G. H. Blackburn and T. L. Mooreman, engineers.

During the afternoon the wind sprang up again, and gradually developed into a 40-mile gale. Hopes were entertained for a time that the C-5 would successfully outride the storm on her moorings, but while the mooring guys held fast, the envelope was damaged by the continuous pitching and yawing of the ship, and eventually the forward rigging guys of the car gave way. It was therefore decided to deflate the envelope, and Lieut. C. G. Little, U. S. N., of the handling party, was pulling the rip cord when a violent gust caused the mooring guys to give way, while the rip cord snapped in the officer's hand. Lieutenant Little then jumped overboard, spraining an ankle, while the C-5 shot upward, dropping the car, and was carried seaward by the storm.

Description of the C-5

The United States naval airship C-5 belongs to the coast-patrol class of lighter-than-air craft, which was developed by the Navy for coastal surveillance and convoy work. This particular ship was built to the designs of the Aircraft Division of the Bureau of Construction and Repair, Navy Department, by Goodyear Tire and Rubber Co., at the latter's plant in Akron, Ohio.

The C-5 is of the non-rigid type, with Goodyear patch suspension and a single car. The envelope, made of doubled rubberized balloon fabric, is 192 ft. in length and 41 ft. 9 in. in maximum diameter, and has a capacity of 178,000 cu. ft., while the car, built by the Burgess Co., of Marblehead, Mass., is 40 ft. long. The envelope maintains its shape by virtue of internal pressure, exceeding in value that of the surrounding atmosphere, which is generated by the slip stream of the twin airscrews. This slip stream is collected by two blower pipes which discharge the air into a duct leading to two ballonets; the latter insure the static trimming of the ship. Additional trim control is afforded by two water bags fitted forward and aft in the bottom of the envelope, as well as by elevators of the conventional type, mounted astern.

Longitudinal and directional stability are secured by fixed horizontal and vertical fins, and steering in the horizontal plane

is effected by means of a balanced rudder. The tail planes are composed of metal frames surfaced with balloon fabric and are rigged to the envelope by the patch system.

The car is suspended from the envelope by the same system, consisting of some fifty finger patches, each of which is tested to withstand a pull of 2000 lb. and consists of four fabric strips disposed in the shape of a hand which are sewn and cemented onto the envelope. This type of rigging, while insuring a very high safety factor, secures a considerable saving of weight over the belly band rigging popularized by the Parseval airships, or the internal rope girder of the Astra-Torres system.

The car is built up around a wooden four-longeron truss girder, stream-lined with appropriate fairing stringers, and is fabric covered. Four cockpits are provided in the car for the crew, disposed from bow to stern as follows: (1) pilot's cockpit, (2) cockpit for commander and assistant pilot, (3) cockpit for engineer and assistant engineer, and (4) cockpit for radio operator. Between the third and the fourth cockpits are fitted the fuel tanks, holding altogether 250 gal. of gasoline, and the oil tanks. All cockpits communicate with one another by means of a gangway. The forward cockpit is equipped with a compass only, as the coxswain is charged exclusively with directional steering; all other instruments are mounted in the second cockpit, whence the ship is navigated. The aftermost cockpit is fitted with a radio apparatus having a sending range of about 150 miles, though messages from a greater distance may be received, and with a radiophone, for communications of lesser distance with ships and shore stations.

The power plant consists of two water-cooled vertical 6-cyl. Union engines, each of which develops 125 hp. at 1350 r.p.m. The fuel consumption, determined for the Navy in a 48-hr. endurance test, is 0.558 lb./hp., and the oil consumption 0.0124 lb./hp. The weight of the engine, complete with two carbureters, two Dixie magnetos, pumps and water piping, is 485 lb., which gives a weight of 3.88 lb./hp.*

This initial weight, which might seem rather high when compared withh the typical airplane engine, is, however, more than compensated for by the very great sturdiness and the low fuel consumption of the Union engine—features which make of it a particularly desirable power plant for airships where endurance flights of 20 hr. are quite normal and cruises of 40 or 50 hr. are far from unusual.

The two engines are mounted on either side of the car on outriggers of steel tubing; cooling is secured by honeycomb radiators fitted in front of the engines.

Hand rails are provided on either side of the car for the handling of the ship on the ground, and cellon windows are let in the forward portion of the car to enable the commander to inspect the ground, or sea, below.

The high speed of the C-5 is from 55 to 60 m.p.h. As the engines consume a total of less than 10 gal. of fuel per hour at a speed of 50 m.p.h., the fuel capacity of the ship would enable her to cover in still air a distance of about 1300 miles without refueling. However, by reducing the speed to 30 m.p.h., the endurance can be increased to 60 hr., that is, 1800 miles. According to the New York *World*, provision has been made on the C-5 for driving the engines on a mixture of gasoline and hydrogen; the latter gas forms an excellent combustible mixture with gasoline, as is explained elsewhere in this issue, and is readily available whenever gas has to be released on account of its expansion or the lightening of the ship due to fuel consumption. Thus, instead of going to waste, the hydrogen, which is normally expelled from the gas valves, would assist in increasing the endurance of the airship.

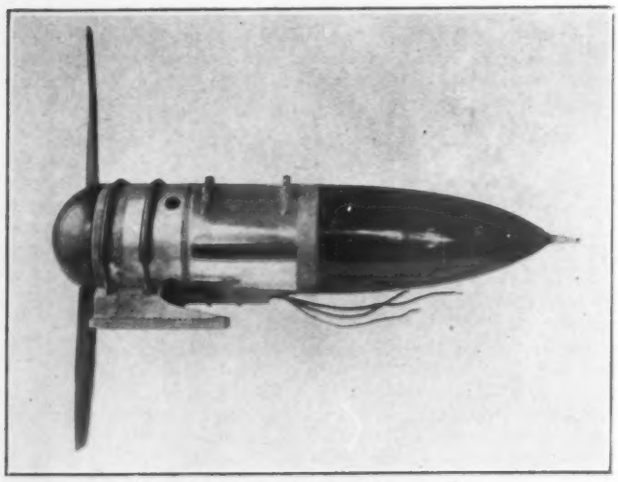
The C-5 is equipped with regular position lights (green starboard and red port lights, and a red tail light) and with a 6-in. Aldis searchlight for signaling to ships and aircraft; the nacelle is internally lighted by electricity, while the instruments are radium-lighted.

The static ceiling is 8600 ft., and the rate of climb 1000 ft. per min.

The full speed endurance is 10 hr.

Aircraft Transmitting Equipment, Type SE-1310

This aircraft transmitting set was designed and built by the International Radio Telegraph Co. of New York to meet the urgent need of an airplane transmitter to cover greater ranges than those in use at present. It was designed especially for use on seaplanes of the HS type, but was first installed on the NC type of flying boats in the recent trans-Atlantic flight. These sets were designed to give a normal operating range of 350 to 400 miles under ordinary or about 250 miles under adverse transmitting conditions, although under more favorable conditions they have a range of considerable distance, such as was demonstrated during the recent trans-Atlantic flight of the NC-1, NC-3 and NC-4 flying boats. During this flight the Navy Department states that these transmitting sets were heard and copied over a distance of 1200 miles.



THE COMPLETE TRANSMITTING SET

The complete set consists of all the accessories necessary to install, repair, and replace broken parts, but only the actual set as installed in the plane will be described.

The transmitter itself consists of a 550 watt, self-excited inductor type alternator, an aluminum sheet or casing, of the same diameter as the generator and attached to the rear thereof, and in which are contained the power transformer and the rotary spark gap. To the end of this aluminum shell is attached a streamlined hood, composed of fabric impregnated with bakelite. This serves as an enclosure for the condenser and the oscillation transformer which are, however, bolted to the aluminum shell extending back from the generator, rather than receiving any support from the hood. The hood also is attached to the aluminum shell, by means of slotted channels and spring dowels, which make it readily removable for inspection and adjustment. The aluminum casting is also provided with a water tight hand hole, by which access may be had to the rotary gap.

The generator itself is a special inductor type alternator, designed for a speed of 5000 r.p.m. and develops from 135 to 150 volts on open circuit at 1000 cycles. The full load voltage is approximately 100 volts. The stator consists of four direct current poles, into each of which are cut four slots for the alternating current winding. The rotor is made with twelve teeth and acts as the inductor. The direct current winding for exciting the field is wound in the slots between the teeth and delivers current to the field through an externally mounted field switch. The switch is arranged so that the alternator field circuit is closed only when transmitting, and in closing the circuit a battery is momentarily connected in to insure its building up.

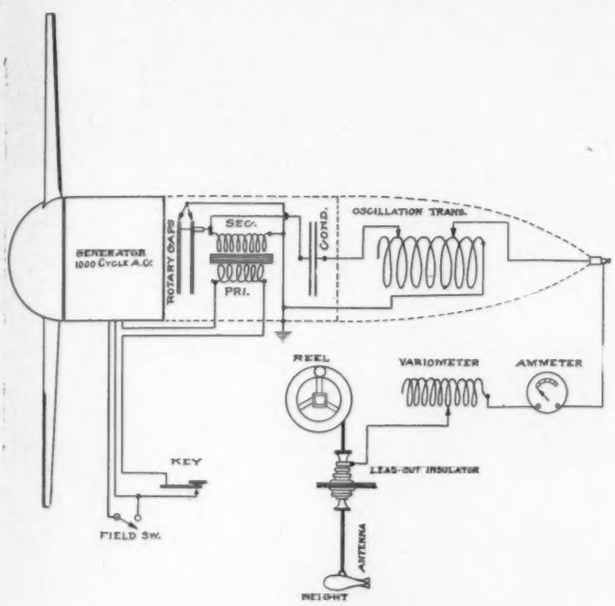
The gap equipment comprises two rotors, one having twelve and the other eight teeth, mounted directly on the generator

* A detailed description of the Union engine appeared in the March 15, 1919, issue of AVIATION AND AERONAUTICAL ENGINEERING.

shaft by an insulating molded hub. This gives the set two different spark tones, 1000 and 666 sparks per second, which greatly increases the selectivity of the transmitter. The fixed element consists of two tungsten electrodes mounted on a holder which can be rotated through 180 deg.; the other electrode is brought into use with the twelve-tooth rotor, while the one located opposite the eight-tooth rotor is inoperative. By means of an eccentric bushing in the bracket by which the electrode holder is mounted on the generator rear bearing housing, the distance between the tips of the rotor teeth and the fixed electrode can be adjusted. The angular adjustment is obtained by loosening the clamp that holds the electrode bracket.

The power transformer is of the closed core type, the ratio of transformation being approximately 1 to 34.

The condenser is of the mica dielectric type, having a capacity of 0.010 mf., and is mounted by means of an aluminum casting which also supports the oscillation transformer.



DIAGRAMMATIC CROSS-SECTION

The latter is of the conductively coupled type and consists of seven turns of No. 10 B and S bare copper wire, wound in grooves in a bakelite cylinder. Three taps are brought out, with suitable terminals for the primary connection, by which the primary can be adjusted to wave lengths of 335, 375, and 425 meters. The terminals for the primary connections are mounted on the base of the oscillation transformer. The coupling taps are brought out to a switch located on the rear end of the oscillation transformer, and permit adjustment to six degrees of coupling.

The antenna used is of the trailing type, consisting of a 250 ft. length of silicon bronze stranded antenna wire to the end of which is attached a stream-lined lead weight. The antenna is brought into the cockpit through insulators having a metallic bushing with flared ends to a reel upon which the antenna is wound when the plane is about to descend. Connection to the antenna is made by a terminal connected to the bushing in the insulator.

The antenna is paid out to its full length, and the open circuit tuned by means of a variometer which is assembled to include a hot wire ammeter for indicating resonance.

The variometer consists of 50 turns of No. 14 B & S bare solid copper wire, wound on a thin, hollow cylinder of micarta. The inductance is varied by means of a trolley, hand operated through a rack and pinion, which moves parallel to the axis of the coil, and makes contact with the bare turns of the coil through a recess cut in the cylinder. The trolley can, therefore, be made to cut in, or out, one turn of wire at a time as it is moved along. The dead end of the coil is connected to the trolley contact and is thereby short-circuited. A copper ring moving with the trolley inside the coil serves to prevent sparking at the trolley contacts by shielding the magnetic lines of force from the turn short-circuited by the trolley.

The transmitter is usually mounted on the boat by means of a special strut or wing fitting, usually on the lower side of the upper frame. On the NC type of trans-Atlantic seaplane a special mounting was arranged on a rear strut in the center of the boat, so that when the boat was not flying, the transmitter could be moved up on the strut into the wash of the propeller of the center engine. This engine could then be run at a speed not sufficient to cause the boat to move, but still sufficient to operate the radio set. A skid-fin antenna is used when operating under these conditions. This antenna amounts to nothing more than a T antenna strung across the top of the boat between the skid-fin of the plane and a lead-in dropped down from the center. The ground is made at the keel of the boat.

The leads from the transmitter are brought through the wall of the boat to the cockpit. In order to make it possible to operate the set from various points of the boat several keys are installed. These keys are of the flame-proof type and are equipped with winker lamps connected to a transformer across the key contacts, which serve to indicate whether or not the line is in use. When no keys are being operated the lights burn continuously until one operator presses his key. Then all lights go out corresponding to the operation of the key.

Loening Monoplanes for Navy

The first Government peace time order for airplanes has been placed by the Navy Department with the Loening Aeronautical Engineering Corp., New York, for the immediate delivery of six special Loening monoplanes which are to be used by the Navy for shipboard observation use.

Recent experiments, started just prior to the close of the war and continued for several months thereafter, have disclosed the remarkable efficiency with which fast high-powered airplanes can be used in the naval service for observation and spotting of gun fire of the battleships.

The machines for the U. S. Navy will be so equipped as to permit of launching off the deck of a ship, as it has been found that the light monoplane type of machine can be accelerated very quickly, particularly when equipped with an engine as powerful as the 300 hp. Hispano-Suiza, which is being used on this type of craft.

The New Air Program

Contracts for at least 500 airplanes of the very latest types will be awarded to American manufacturers under plans prepared by the Army Air Service and sent to Secretary Baker for his consideration. The primary purpose would be to keep the industry in such condition as would insure its rapid expansion to meet the requirements of a national emergency.

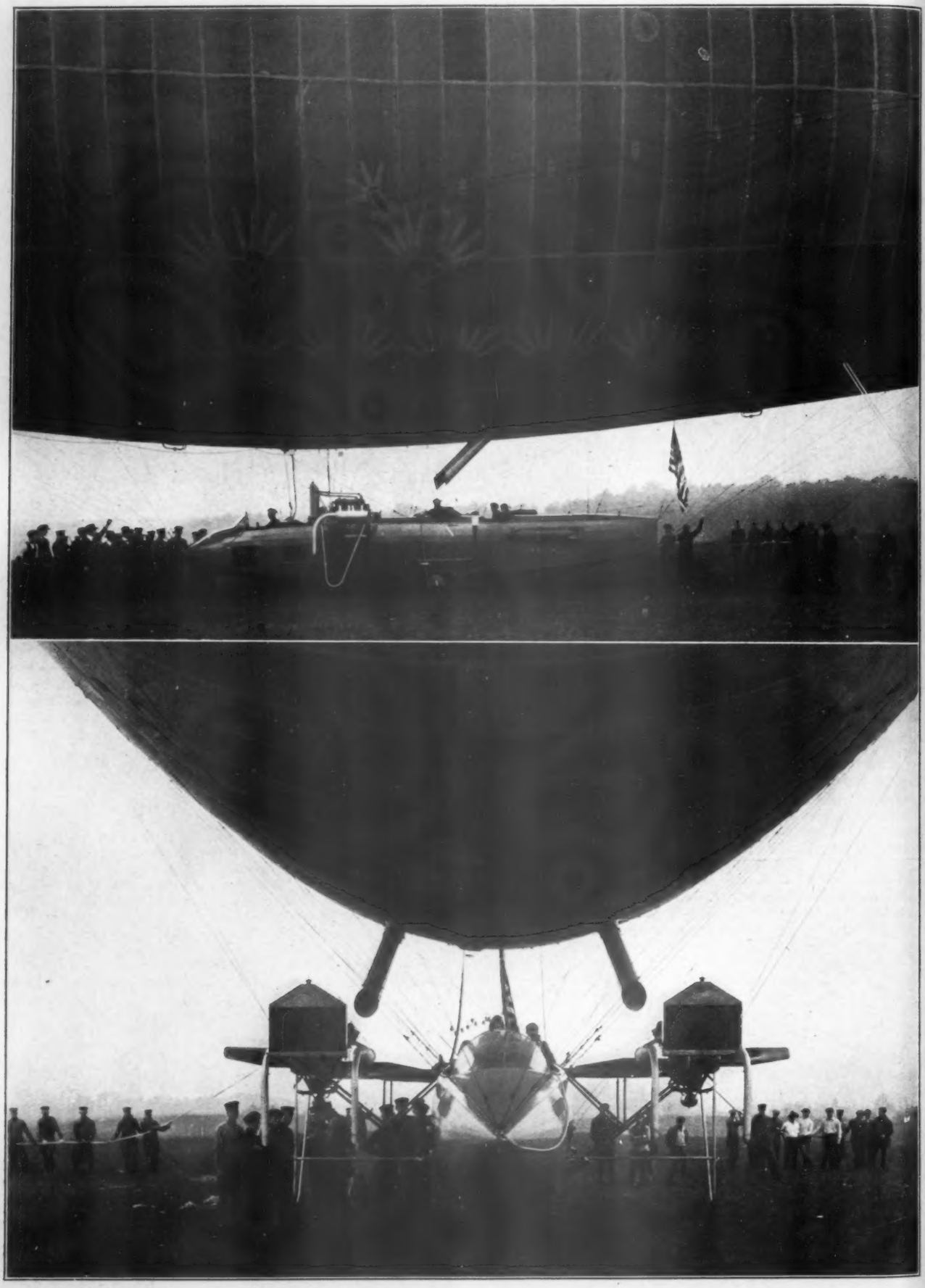
Seven types of planes have been approved by the Air Service as representing the most modern developments in the science of aviation. They are the Le Pere reconnaissance plane, the Loening fighting monoplane, the Thomas-Morse scout, the U. S. D. 9-A day bomber, the Vought advance training plane, the Martin day bomber, and the Ordnance Engineering Corp. pursuit plane.

Air Commission to Europe

Benedict Crowell, Assistant Secretary of War, and a number of military and civilian aviation experts sailed on May 22 for Europe to study possibilities of developing the science of aviation along the lines of civil usages.

Included in the party are Lieut.-Col. James A. Blair, of the general staff; Capt. Harry C. Mustin, U. S. N.; S. S. Bradley, of the Manufacturers' Aircraft Association; G. H. Houston, President of the Wright-Martin Aircraft Corp., C. M. Keys, Vice President of the Curtiss Aeroplane and Motor Corp., and Howard Coffin, of the Council of National Defense.

Col. Halsey Dunwoody, Chief of the Air Service overseas, will join the party in France.



SIDE AND FRONT VIEWS OF THE CAR OF THE U. S. NAVAL AIRSHIP C-1. LENGTH OF CAR, 40 FT. TWO HISPANO-SUIZA 150 HP. ENGINES

Photo U. S. Naval Air Service

Course in Aerodynamics and Airplane Design

Part III.—Experimental Aeronautical Engineering

By Alexander Klemin

Technical Editor, Aviation and Aeronautical Engineering; Consulting Engineer, Aerial Mail Service; Consulting Aeronautical Engineer

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Section 5. Full Flight Testing

Physical Data for the Atmosphere—Full flight testing may have one of two objects: first, the routine testing of a new airplane for speed at different altitudes, climb, stability and maneuverability; second, research testing for purposes of aerodynamical investigation. We shall confine ourselves to a consideration of routine performance testing solely. Even routine performance testing involves the possibility of many errors, and requires great care and, above all, standardized methods,

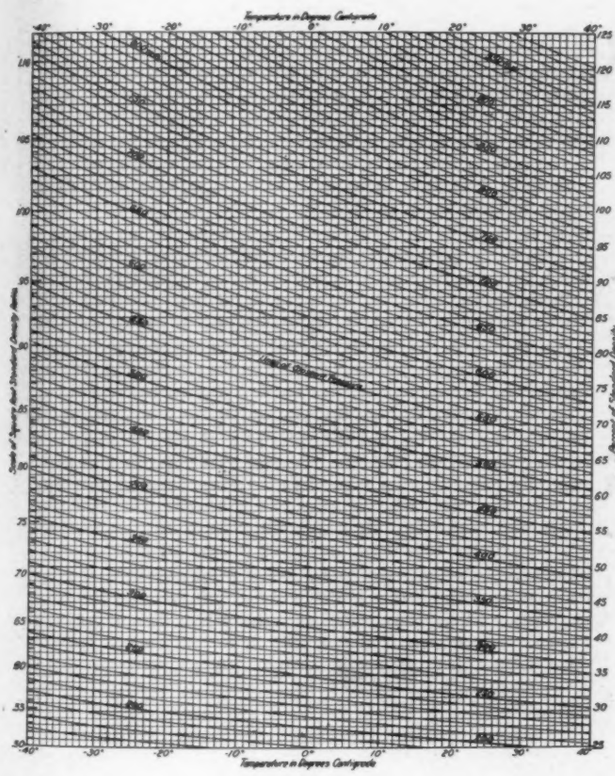


FIG. 1

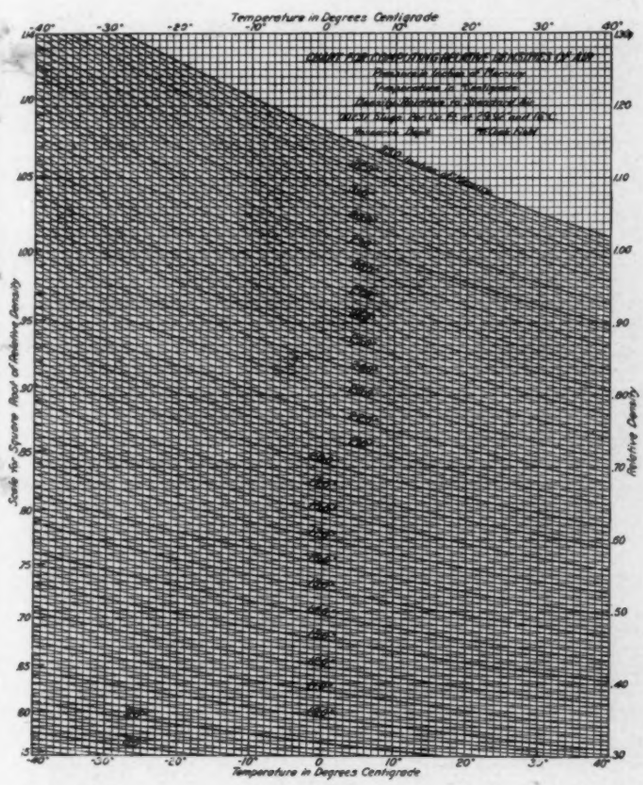


FIG. 2

in order that true comparisons may be made between tests on different planes.

Formula for Density of Air—For a perfect gas, $PV = RT$ is a well-known thermodynamic law, where P = pressure in suitable units, V = volume of unit weight, R = a constant, and T = absolute temperature.

From this it follows that

$$\frac{1}{V} = \frac{P}{RT},$$

and since $\frac{1}{V}$ = density in appropriate units,

$$D = \frac{P}{RT} = \text{density formula for all gases.}$$

Or, in more convenient form,

$$D = \frac{PC}{T} \text{ where } C = \frac{1}{R} = \text{some constant.}$$

From this also follows the useful equation

$$\frac{D_1}{D_2} = \frac{P_1 T_2}{P_2 T_1}$$

The equation $D = \frac{PC}{T}$ can be expressed in a number of units.

(*a*) *Density in grams per cubic meter.*
Density of air at 0 deg. Cent. (or 32 deg. Fahr.) and 760 mm. (or 29.92 in.) equals 1292.8 gm. per cu. m.

Standard density of air at 16 deg. Cent. (or 60.8 deg. Fahr.) and 760 mm. = 1221 gm. per cu. m.

1.... $D = \frac{P \times 464.39}{T}$

where P = pressure in millimeters of mercury at 0 deg. Cent.
T = absolute temperature in deg. Cent.

2.... $D = \frac{P \times 11795}{T}$

where P = pressure in inches of mercury at 0 deg. Cent.
T = absolute temperature in deg. Cent.
= reading on Centigrade scale + 273 deg.

3.... $D = \frac{P \times 21231}{T}$

where P = pressure in inches of mercury at 0 deg. Fahr.
T = absolute temperature on Fahr. scale
= reading on Fahr. scale + 459.4.

(*b*) *Density in pounds per cubic foot.*

Density of air at 0 deg. Cent. (or 32 deg. Fahr.) and 760 mm. (or 29.92 in.) = .08053 lb. per cu. ft.

Standard density of air at 16 deg. Cent. (or 60.8 deg. Fahr.) and 760 mm. (or 29.92 in.) = .07608 lb. per cu. ft.

At varying pressure and temperature, considering D the density in lb. per cu. ft.,

$$(1)\ D = \frac{P}{T} \times .02902$$

where P = pressure in mm. of mercury at 0 deg. Cent.
T = absolute temperature on Cent. scale.

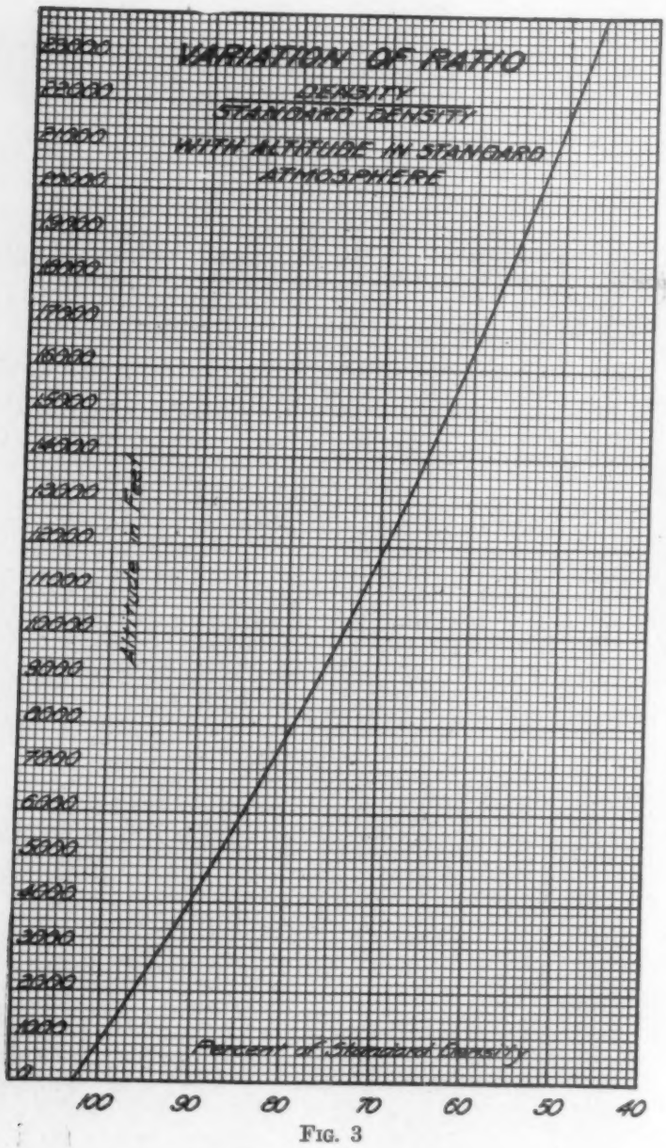


FIG. 3

$$(2)\ D = \frac{P}{T} \times 0.7347$$

where P = pressure in inches of mercury at 0 deg. Cent.
T = absolute temperature reading on Cent. scale.

$$(3)\ D = \frac{P}{T} \times 1.2366$$

where P = pressure in inches of mercury at 0 deg. Fahr.
T = absolute temperature on Fahr. scale.

Reduction to percentage of Standard Density—The standard density of 60.8 deg. Fahr. (or 16 deg. Cent.) and 29.92 in. (760 mm.) has been adopted officially in British full flight testing, and it would indeed be excellent practice to adopt this standard in American work. Air speed indicators are calibrated to this standard density, and density at altitude is referred to the same standard. It becomes very convenient to refer to this density in many computations, hence charts have been drawn up, as shown in Figs. 1 and 2. These charts are self-explanatory and will be found very useful. In Fig. 1 the temperature is in Centigrade units and pressure in millimeters, while in Fig. 2 the temperature is in Centigrade units and the

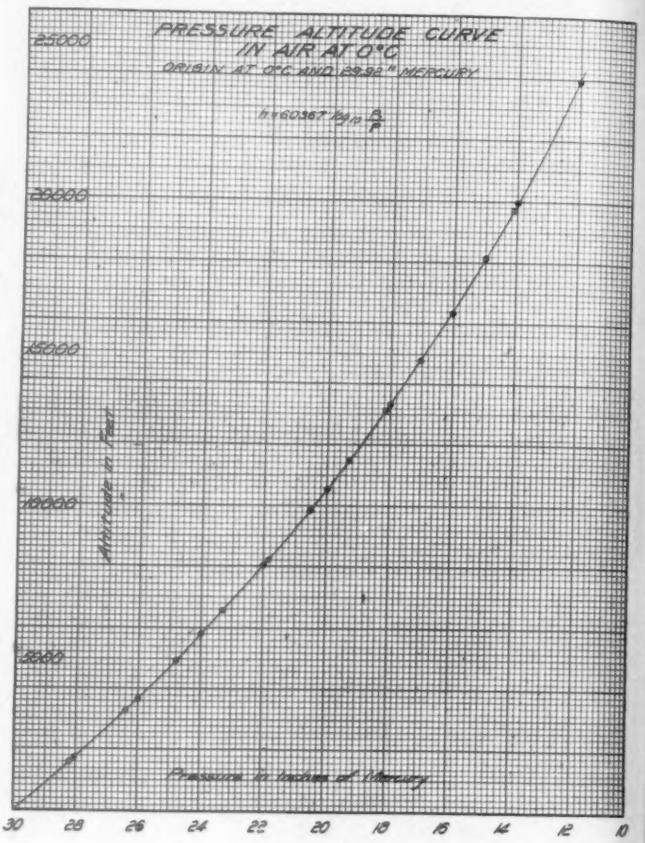


FIG. 4

pressure is in inches of mercury. The curves were obtained by using the density formulae of the preceding paragraphs.

Standard Atmosphere—In computing the results of climb and speed tests, under varying atmospheric conditions, the British have adopted a *standard atmosphere* in which a definite ratio of the standard density at 16 deg. Cent. and 760 mm. is taken to correspond to every altitude.

In the accompanying Table 1 the height in feet and corresponding percentage of standard density are tabulated, and a curve between the two is given in Fig. 3.

Performance, both as regards climb and speed, is not de-

TABLE I

Density Values at Various Altitudes

Height in Feet	Percentage of Standard Density
0	102.6
1,000	99.4
2,000	96.3
3,000	93.2
4,000	90.3
5,000	87.4
6,000	84.6
6,500	83.3
7,000	81.9
8,000	79.2
9,000	76.5
10,000	74.0
11,000	71.7
12,000	69.5
13,000	67.3
14,000	65.2
15,000	63.0
16,000	61.1
16,500	60.1
17,000	59.1
18,000	57.1
19,000	55.2
20,000	53.3

pendent on altitude, but solely on density. Hence the adoption of a standard relation between altitude and density furnishes a true basis of comparison, and still gives a concrete reference to altitude, but eliminates variations due to changing weather

Relationship between Pressure, Temperature and Altitude—For a complete understanding of the working of an altimeter or aneroid barometer, it is important to establish the fundamental formulae for variation of pressure, with temperature and altitude.

If two layers are a distance dh apart in the atmosphere, and in equilibrium under the action of gravity, and the density of gas is D, then the variation in pressure per unit area is given by the equation

$$dP = -Ddh$$

the negative sign being present since the pressure is diminishing.

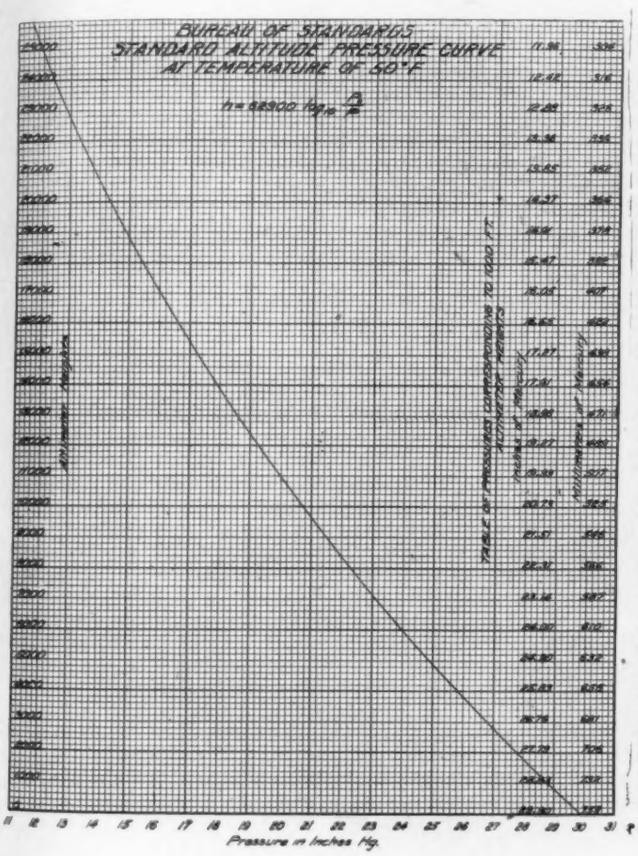


FIG. 5

Now since $D = \frac{P}{RT}$ if T remains a constant, $D = \frac{P}{A}$ where A is a constant equal to $RT = \frac{P}{A}$.

The equation $dp = -Ddh$ can be written $\frac{A\,dP}{P} = -dh$.

Integrating this equation, we obtain between limits P_o and P,

$h = A \log_e \frac{P_o}{P}$, which is known as Halley's formula.

To transform to common logarithms, we divide by the constant 0.4343 and

$$h = \frac{A}{0.4343} log_{10} \frac{P_o}{P} = \frac{A}{0.4343} (\log P_o - \log P.)$$

Halley's formula immediately gives a relation between the pressure of air and height where the temperature remains constant. It can be written numerically for either metric or British units.

Thus, if $T = 0$ deg. Cent., and pressure $P_o = 760$ mm. of mercury or 10,333 kgm. per sq.m., then

$D = 1293$ gm. per cu.m.,
hence $= 1.293$ kgm. per cu.m.,
and $A = \frac{P}{D} = \frac{10333}{1.293} = 8000$

while $\frac{A}{0.4343} = 18{,}400$

so that the equation becomes

$$h = 18{,}400\ (\log_{10} P_o - \log_{10} P)$$

In English units $h = 60{,}367 \log_{10} \frac{P_o}{P}$

In Fig. 4 a curve giving this relationship is shown.

Correction of Halley's formula for Temperature—Halley's formula takes no cognizance of variations due to change in temperature, to atmospheric humidity, to variation in gravity at varying latitudes, and to variation in gravity at varying

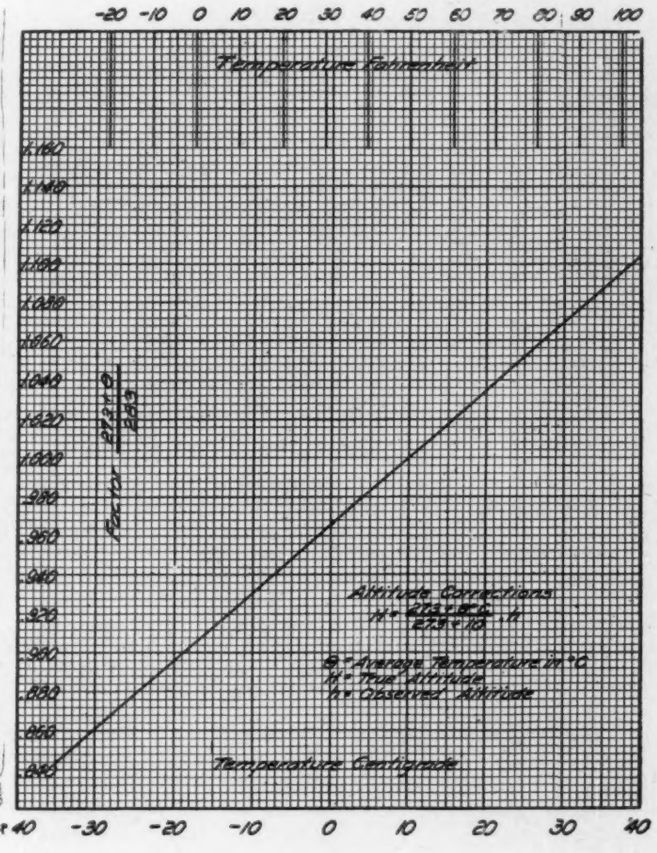


FIG. 6

distances from the center of the earth. Laplace originally developed a formula which took cognizance of all these variations. The most important is that due to temperature.

The first equation in the derivation of Halley's formula is:

$$\frac{A\,dP}{P} = -Ddh$$

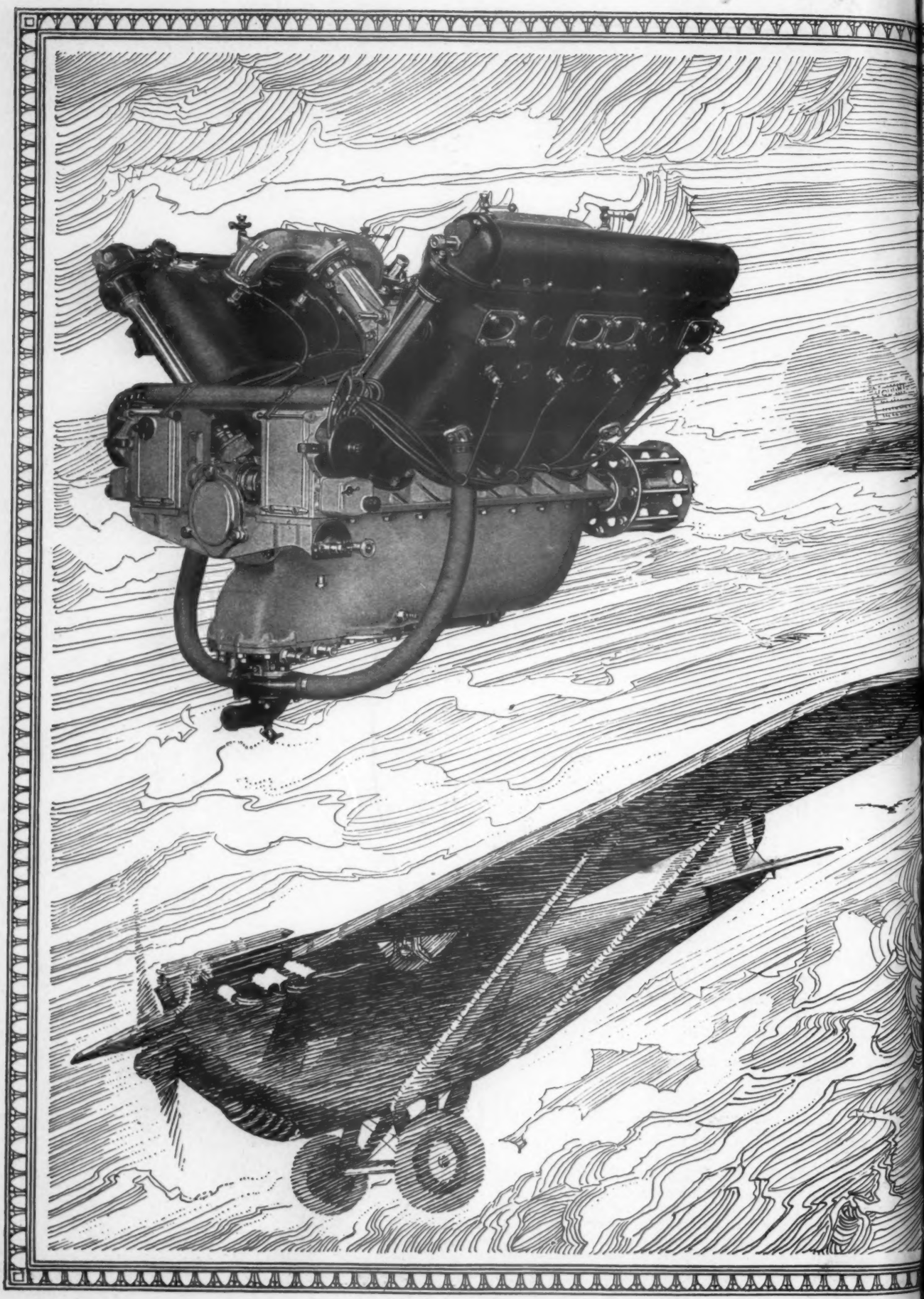
This is true where temperature remains constant. For variation in temperature only, $\frac{D_1}{D_2} = \frac{T_2}{T_1}$, where T_1 and T_2 are in absolute temperature units.

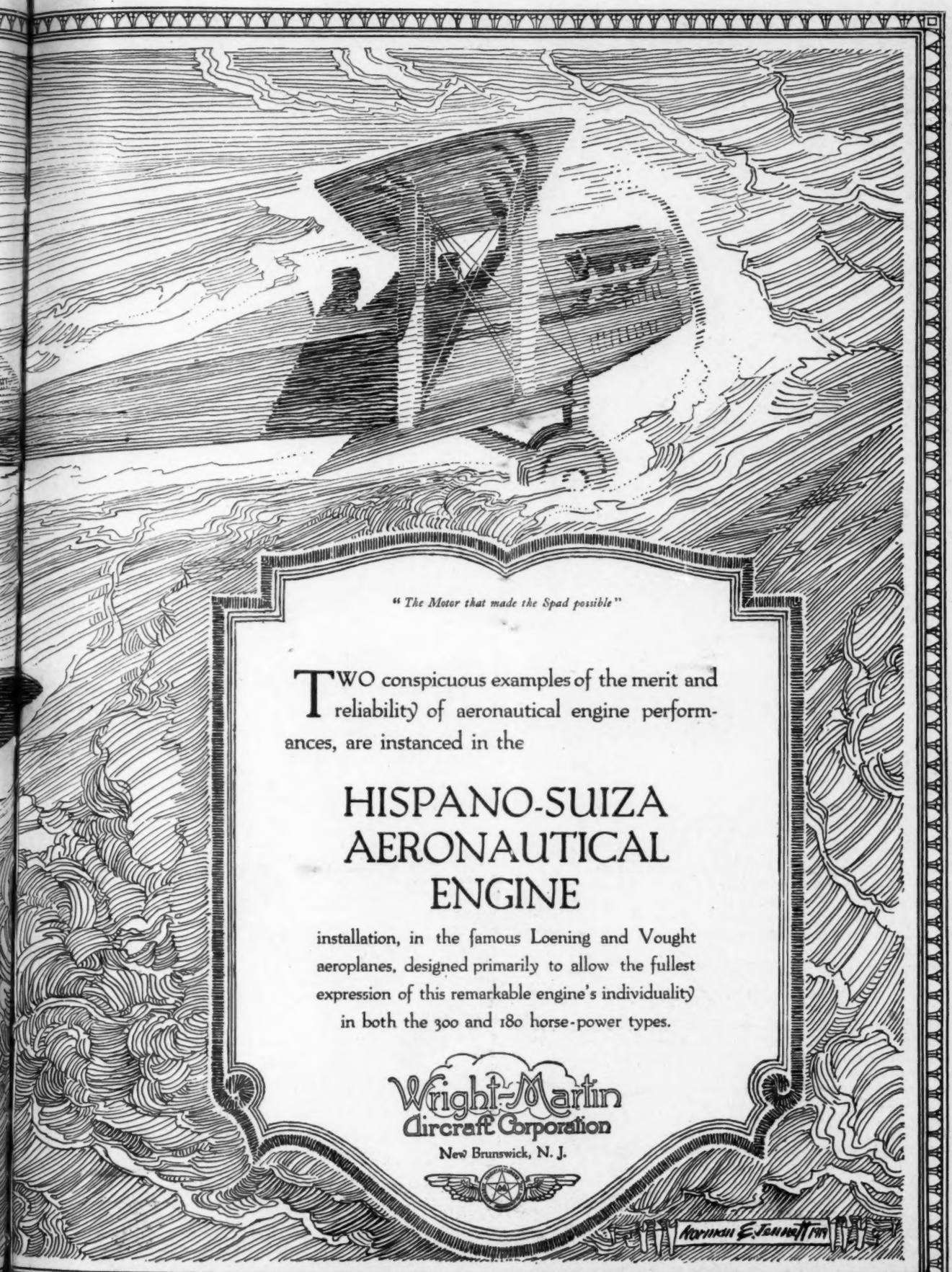
Accordingly, if the constant A in Halley's formula has been deduced for a certain temperature T_1, the integration will become

$$\int \frac{A\,dP}{P} = \int -D \frac{T_2}{T_1} dh,$$

or

$$\int \frac{A\,dP}{P} = \int -D \frac{t_a + t_2}{t_a + t_1} dh$$





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installation, in the famous Loening and Vought aeroplanes, designed primarily to allow the fullest expression of this remarkable engine's individuality in both the 300 and 180 horse-power types.

Wright-Martin
Aircraft Corporation
New Brunswick, N. J.

where t_1 and t_2 are in Cent. or Fahr. units, and t_a is 273 on Cent. scale and 459.4 on Fahr. scale.

Since temperature does not vary in any direct manner with the height, it is impossible to integrate this directly. Between two altitudes where the distance is not too great, it is sufficiently accurate to take the mean temperature. In finding altitudes of several thousand feet where temperature is recorded at intervals, the computations are repeated at these intervals and sufficiently accurate results are obtained. In Fig. 6 a correction chart for temperature is given.

Bureau of Standards altitude-pressure curve—If f is the vapor pressure of water in the atmosphere, expressed in the same units as P, then when D is calculated from values of P,

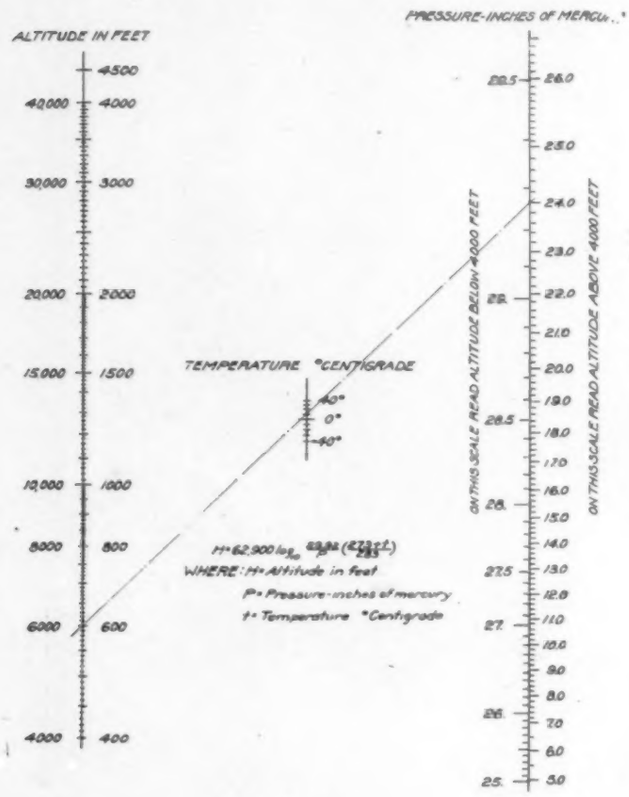

FIG. 7

instead of P the expression $P - 0.377\ f$ is employed. This is a very small difference. In the Bureau of Standards altitude-pressure curve (Fig. 5) allowance has been made for humidity. This curve is used for the commercial calibration of altimeters and barographs, which are always calibrated for a temperature of 50 deg. Fahr.

The modified Halley formula for this curve is

$$H = 62900\ \log_{10}\frac{P_0}{P_1},$$

and the values for the curve are given in table II. Hence for any altimeter used purely as a pressure instrument, the pressure corresponding to any altitude can be obtained at once.

Alignment Chart for Altitudes—In Fig. 7 is given an alignment chart for altitudes based on the formula,

$$H = 62900\ \log_{10}\frac{P_0}{P},$$

at an isothermal temperature of 10 deg. Cent., or 50 deg. Fahr., and the temperature correction of

$$\frac{(273 + t)}{283}.$$

This chart would only be absolutely true for high altitudes when the correction temperature is constant throughout. It is approximately true if the mean temperature between the two altitudes is found. It is almost exactly true if differences of altitude are sought and these differences are small.

To use the chart it is only necessary to lay a straight edge across it diagonally through the correct pressure and temperature points; the reading where the straight edge crosses the altitude scale is the corresponding height. A piece of fine silk thread tightly stretched between the thumbs forms a very convenient straight edge. The altitude scale is graduated to read heights from 4000 to 40,000 ft. on the outside scale and from 400 to 4000 ft. on the inside scale. The pressure scale is graduated both sides to correspond with the altitude scale. It is only necessary to remember that whenever the pressure lies on the inside scale the correct altitude will be found on the inside scale also.

TABLE II

Calibration Table for Altimeter

T = 50 Deg. Fahr.

Barometer	Equivalent Ft.	Permissible Performance Error in ft
29.90	0	0
28.83	1,000	50
27.79	2,000	50
26.79	3,000	50
25.83	4,000	50
24.90	5,000	100
24.00	6,000	100
23.14	7,000	100
22.31	8,000	150
21.51	9,000	150
20.73	10,000	200
19.99	11,000	200
19.27	12,000	200
18.58	13,000	250
17.91	14,000	250
17.27	15,000	250
16.65	16,000	300
16.05	17,000	300
15.47	18,000	300
14.91	19,000	350
14.37	20,000	350
13.85	21,000	400
13.36	22,000	400
12.88	23,000	400
12.42	24,000	500
11.96	25,000	500

Aeronautical Patents

ISSUED MARCH 4, 1919

1,296,069—To John F. Kahl, Brooklyn, N. Y. Flying-machine.

1,296,310—To Herbert T. Nowell, Billings, Mont., assignor to Frederick C. Austin, Chicago, Ill. Projectile.

1,296,578—To Clyde L. Welsh, Pittsburgh, Pa., assignor to Welsh Adjustable Aeroplane Co., Pittsburgh, Pa. Aeroplane.

1,296,551—To Daniel Pecher, Princeton, British Columbia, Canada, assignor of one-third to Tom Guyton and one-third to Joseph Pawlick, Princeton, British Columbia, Canada. Aeroplane.

1,295,968—To Everard Richard Calthrop, London, England, assignor to E. R. Calthrop's Aerial Patents, Ltd., London, Eng. Parachute.

1,295,970—To Melvin Bent Cumbler, Harrisburg, Pa. Aeroplane.

1,296,528—To John F. Kinney, Bumboldt, Kans. Aeroplane.

ISSUED MARCH 18, 1919.

1,297,746—(Withdrawn.)

1,297,795—To Charles R. Cavanagh, Boston, Mass. Flying machine.

1,297,604—To Thomas B. Smith, Cheriton, Va. Airplane.

1,297,331—To Serge Vincent De Bolotoff, London, England. Means to receive strut ends in airplanes and other structures.

1,297,882—To William D. McCormack, Nashville, Tenn. Attachment for aircraft to render same invisible.

ISSUED MARCH 25, 1919

1,298,080—To Harry C. Mougey and James M. H. Jacobs, Dayton, Ohio, assignors to the Dayton Metal Products Co. Fuel tank.

1,298,615—To Le Roy John Wilkinson, Omaha, Nebr. Safety apparatus for aviators.

1,298,038—To Frederick Michael Green, Parkside, Coventry, England, assignor to Siddeley-Deasy Motor Car Co., Ltd., Parkside, Coventry, England. Landing chassis.

1,298,625—To Paul G. Zimmermann, Buffalo, N. Y., assignor to Curtiss Aeroplane & Motor Corp. Landing gear for airplanes.

1,298,133—To Henry Wilson-Fox, London, England. Aircraft.

1,298,487—To Spenser A. Flower, London, England. Airship.

1,298,338—To Lewis Montgomery Murray Hall, Ealing, London, England. Airplane.

1,298,082—To John Neff, Sr., West Hoboken, N. J. Airship.

1,298,120—To George F. Swain, Chicago, Ill. Flying machine.

1,298,516—To Henry Kleckler, Buffalo, N. Y., assignor to Curtiss Aeroplane & Motor Corp. Aeroplane-Control bridge.

1,298,515—To Henry Kleckler, Buffalo, N. Y., assignor to Curtiss Aeroplane & Motor Corp. Fuselage clip.

1,296,775—To Nelson W. Dalton, Buffalo, N. Y., assignor to Curtiss Aeroplane & Motor Corp. Aerofoil construction.

1,296,790—To William L. Gilmore and William E. Valk, Jr., Buffalo, N. Y., assignors to Curtiss Aeroplane & Motor Corp. Radiator for aeroplanes.

Veneer Body Construction*

Test of USXB-1 Bodies

Widman USXB-1 Type—This body, built for a Bristol-type two-seater fighter, had longerons of solid gray elm, with laminated skin and bulkheads (Fig. 5). The outer plies in the bulkheads were alternately of elm and birch, while the core was of elm in some cases, and of poplar mahogany and birch in others. The skin was secured to the bulkheads with glue and brass screws; it varied in thickness from 3/16 to 5/32 in., the number of laminations ranging from three to seven, with the face grain in all cases longitudinal. The number of laminations in the bulkheads ranged from seven to thirteen, with a total thickness of from ½ to ⅞ in.

The weight of the complete body was 206 lb., apportioned as follows:

	Pounds.
Longerons	30.5
Bulkheads	60.0
Engine bearers, slot bearers, shelf	19.0
Flooring	15.5
Skin	52.0
Screws, nails, glue	4.5
Finish	18.5
Total	206.0

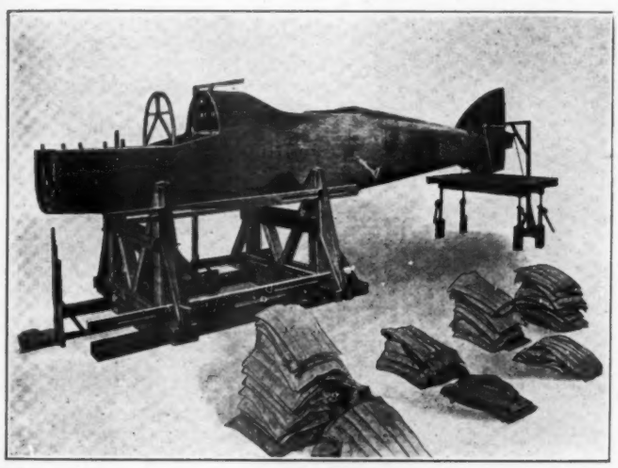

FIG. 5. WIDMAN USXB-1 FUSELAGE SET UP FOR TEST

Up to a load factor of 7 this body showed no signs of failure except for a slight buckling of the skin on the bottom immediately in front of the rear support. After an application of load 7, however, the front plate fitting bolted to the body failed by shearing out the lift wire holes. Owing to this local failure it is impossible to say how much greater load this body could have withstood before general failure would have occurred. There was, however, no failure at any of the joints, which were long scarfs pressed together, and the toughness of elm proved highly satisfactory, giving probably higher total strength than the spruce or birch and poplar bodies of the same type which were tested subsequently.

At the time of failure the total load on the body supports was 17,850 lb., of which 4870 lb. were on the front support, and 13,070 on the rear, giving an equivalent tail loading of 51.8 lb. per sq. ft.

Davies-Putnam USXB-1 Type No. 1—This, the first of a series of veneer bodies made by the Davies-Putnam Co. for the USXB-1 two-seater fighter, proved quite a successful and typical construction (Fig. 6).

The veneer skin had spruce face plies with the grain longitudinally throughout, and had layers of cotton fabric between all plies. As in the previous type the skin was not the same throughout the body, but ranged from two to three plies with a total thickness of from 1/12 to 5/32 in. It was secured to the bulkheads and longerons with nails and glue.

A detail drawing of the bulkhead at station 7, where the point of attachment for the rear lift wires was located, is shown in Fig. 7. Most of the other bulkheads were narrow, with a minimum width of ⅝ in. and with thicknesses ranging from ¾ to 1 in. in the front portion, and ⅜ to 1 in. in the rear. The four rearmost bulkheads extended beyond the body so as to form the framework for the upper and lower fins.

There were four longerons, ash forward and spruce aft, the upper being spliced at station 8, and the lower between stations 6 and 7 (Fig. 8). The scarfed surfaces of these splices were grooved in such a manner that a cross-section through them would show a row of teeth ⅛ in. deep, this being done to increase the glued area. All splices were wrapped with tape and glued.

This body weighed, as tested, without wing anchorage

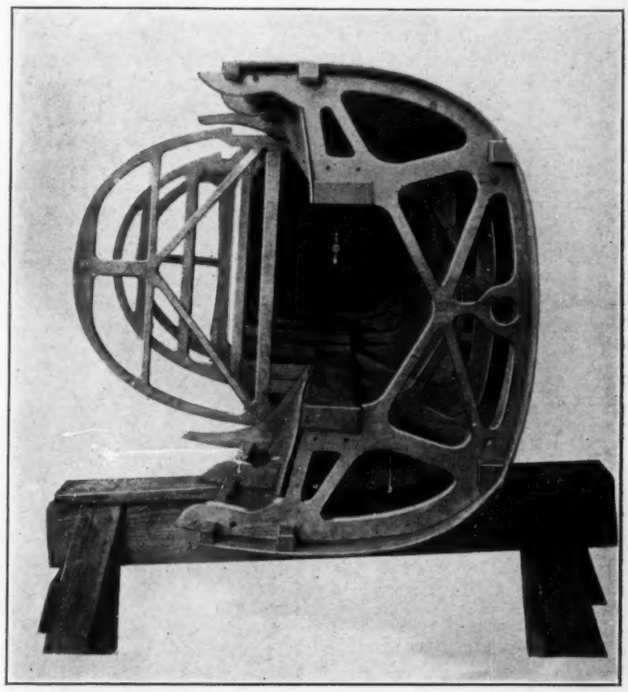

FIG. 6. FRONT END VIEW OF THE DAVIES-PUTNAM USXB-1 TYPE 1

fittings, 163 lb., apportioned as follows:

	Pounds.
Bulkheads	40
Longerons	25
Incidentals	34
Skin	64
Total	163

In the first test the body was supported directly on a test stand by wooden blocks cut to the contour of the bottom and padded with felt. Up to a dynamic loading of 5 no failure occurred. The test was then discontinued and the body set up supported by regular fittings, but the second test turned out badly owing to failure of one of the supports. It was quite clear, however, to observers that this body could have withstood a dynamic loading of 6.

Davies-Putnam USXB-1 Type No. 2—This body differed from the one just described mainly in that the skin was made of spruce plies with cotton sheeting between. Bottom and sides from station 1 to 10 (Fig. 8) were three-ply with the grain of the face plies running longitudinally. The latter were 1/16 in. thick, and the core 1/24 in. thick; the whole was sanded down to a thickness of ⅛ in. The remainder of the skin was of two-ply of 1/24 in. thickness per ply, the whole being sanded down to 1/16 in. thickness.

The bulkheads were of plywood varying from three-ply ⅜

* *Concluded from last issue.*

in. thick to eleven-ply 1 in. thick. It is noteworthy that the longerons were very nearly in line with the side of the bulkheads, so that there was no eccentricity of action of the shear stress such as caused failure in some of the USC-1 bodies previously tested.

The longerons were identical with those of the previous type. In all cases the curved face of the longeron was next to the skin.

This body withstood a dynamic loading of 7.5 before final failure occurred and thus proved of very satisfactory strength, as compared with previous examples, which is attributed to the elimination of local weaknesses, the distribution of the grain and the use of fabric between the plies of the skin. There were signs of strain in the sides and wrinkling of the skin long before actual failure occurred, but the latter is much less serious in a body having a layer of fabric between the plies of the skin, the fabric furnishing considerable resistance to buckling and splitting.

Davies - Putnam USXB-1 Type No. 3—This body was practically identical with the two just cited, with the exception of the following essential structural changes:

The bottom and the sides from stations 1 to 10 (Fig. 8) were of three-ply spruce 5/32 in. thick overall, with no fabric between the plies. The face plies in this portion were $\frac{1}{16}$ in. thick with longitudinal grain, while the core was 1/24 in. thick with transverse grain. The skin in the rear portion of the body was $\frac{1}{8}$ in. thick, consisting of outside plies 1/24 in. thick with longitudinal grain and a core of 1/24 in. thickness with transverse grain.

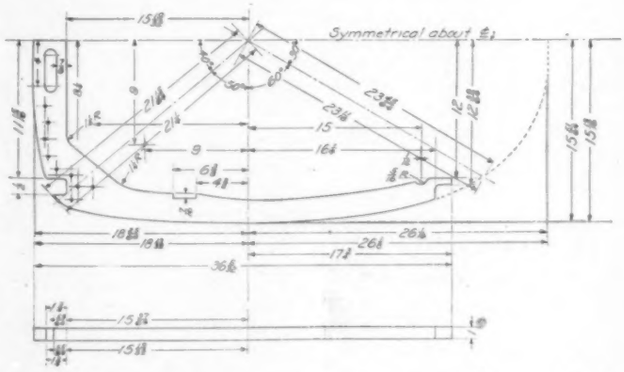

FIG. 7. BULKHEAD OF DAVIES-PUTNAM USXB-1 BODY NO. 1

Some of the bulkheads were $\frac{3}{4}$ and $\frac{7}{8}$ in. thick, made of nine-ply wood, while others were 1 in. in thickness, made of eleven-ply. The bulkhead at station 7 formed the point of attachment for the lift wires, and annular reinforcement strips were fastened to the bulkheads, varying from 2 in. at this point to $\frac{5}{8}$ in. in the rear portion.

The upper longerons were of ash from stations 1 to 9, and of spruce in the rear sections, while the lower longerons were throughout of spruce.

Under a dynamic loading of 6.5 longitudinal cracks commenced to show in the skin near station 7, giving evidence of high shearing stresses at that point. These cracks increased with the next increment of load, and under a factor of 7 the upper longerons split at station 7 and the skin failed near by due to the vertical tension.

This test showed that the omission of fabric between the plies slightly reduced the strength of this body, for the Davies-Putnam Type 2 body had a lighter skin throughout than Type 3 and also had a smaller total weight, yet it developed a higher strength than the third body, which is highly instructive.

Recommendations

As a result of the above tests on veneer type airplane bodies the following principal recommendations may be set down for the use of airplane designers:

(1) The veneer skin should be made with a large proportion of the grain running longitudinally and with the face plies of hardwood.

(2) The use of real longerons (not merely stringers) is sound.

(3) The stiffening of the veneer skin with the usual disposition of bulkheads is not at all difficult; excessively strong bulkheads are not required for this purpose.

(4) When properly stiffened by bulkheads, the bottom of the skin has a decided compression value; consequently it is superfluous to use excessively strong lower longerons.

(5) The skin is considerably strengthened by the use of cotton sheeting between the plies.

(6) Care should be exercised to see that the joints or splices in the skin do not occur at points of great stress.

(7) The upper longerons should be strengthened at cut-outs such as the cockpits.

(8) Bulkheads should be so designed that they will stand up well under local reactions and bending moment applied by the lift wires.

(9) Very careful manufacture should be maintained in order to insure good uniform results.

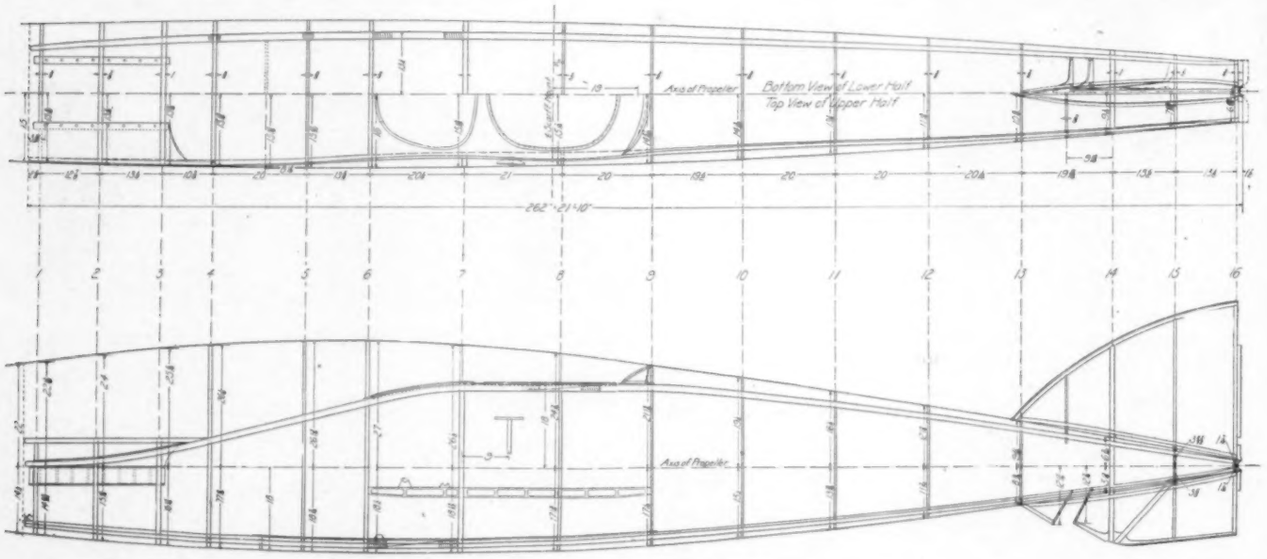

FIG. 8. ASSEMBLY DRAWING OF THE USXB-1 VENEER FUSELAGE

higher strength than the third body, which is highly in-

For the benefit of airplane designers a general assembly drawing of a typical veneer fuselage for the USXB-1, or Bristol type combat airplane, is illustrated in Fig. 8, with the principal dimensions and distances of stations. All station numbers in the description of the USXB-1 refer to this drawing.

Tailoring of Airship Envelopes

By R. H. Upson

Considerable interest has developed both abroad and in this country in regard to the established American practice of "tailoring" non-rigid envelopes, which gives them certain advantages usually thought peculiar to rigid airships without spoiling the desired symmetrical shape. This article does not deal with the detail of pattern calculation, which is a mere mathematical process, nor with the theory of water models and static design in general, but simply sets forth some basic notions underlying this subject.

As a rule it is necessary to tailor a non-rigid envelope unless all the bending moments are balanced against each other at each point along the bag. If carefully calculated, this can be done by adjusting the following items in correct proportion:

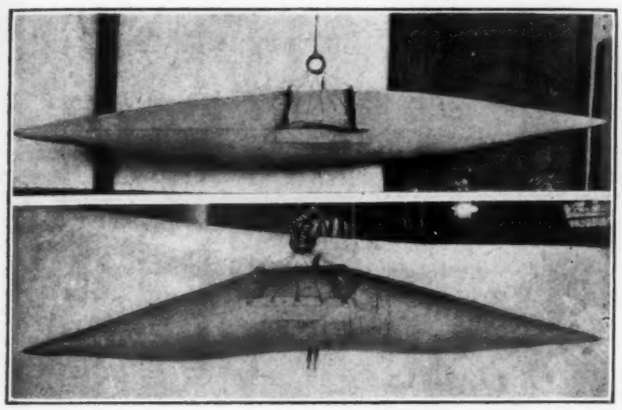

FIG. 1 (TOP). AIRSHIP MODEL INFLATED WITH AIR
FIG. 2 (BOTTOM). THE SAME, FILLED WITH WATER

Size and shape of envelope, length and weight of car, distance between car and envelope, angle of suspension, size and position of ballonets, weight and location of fin group, weight and position of detached power plants, gasoline tanks, etc.

But tailoring is not always advisable, as, for instance, when the general design and purpose of the ship brings the various component parts into a position which makes it convenient to approximate a good envelope form by other methods. This allows, however, a very limited choice in the position of various items, such as car, fins, ballonets and fuel tanks. These requirements are different for almost every different design of airship, and in but few cases do they work out conveniently to a distribution of load which in itself will eliminate distortion in the gas bag.

When the loads (bending moments) are not distributed uniformly along the gas bag, a rigid envelope will hold its shape, but a non-rigid will be strained or bent under the influence of tension and shear. A rather typical form of distribution is shown in the accompanying illustrations. This is a small water model, made of parallel fabric to show better how it distorts. Fig. 1 shows the model inflated with air, while Fig. 2 shows the same model inflated with water, and the photograph turned right side up illustrates the appearance of the gas-filled balloon.

The parallel fabric has practically no resistance to shear, hence the pronounced double S-shape curve which is formed. Here the effect of shear is large compared to that of the direct tension. It will be noted that the ends of the inflated balloon curve opposite to what would be expected from the force of gravity; also, that in spite of distortion the length of the top curve from point to point is approximately the same as that of the bottom curve. If the fabric had no stretch, the top and bottom curves would be exactly the same length, but the shape would not look very different. This is approximately the kind of curve assumed by the early Lebaudy airships in France (which were built of parallel fabric), and to a lesser and modified degree by any non-rigid bag with a single car.

The proper amount of tailoring in Goodyear airships is determined:

(*a*) By water model tests showing the amount of distortion necessary to be overcome.

(*b*) By corrections based on the form of the first airship of any new series.

(*c*) By judgment based on observation of similar types of ships and a comparison of bending moments.

The tailoring is done by cutting out "pie" shaped vertical strips from either the top or bottom of the balloon or both. It is found by experiment that these strips may be as wide as 12 in. without appreciably straining the fabric or unduly localizing the effect. Usual practice, however, in small Goodyear airships has been to standardize on strips of 3 in. maximum width.

The final aim may be set down as follows:

(*a*) To get a balloon which is near enough symmetrical in shape to keep the resistance down to a minimum.

(*b*) To get the horizontal fins parallel to the main axis.

(*c*) To produce a balloon which is straight and neat in appearance.

(*d*) To keep the fabric stresses within proper limits.

Once an envelope is properly tailored it will hold its shape, on the average, indefinitely. The tailoring is based on the usual conditions in regard to cable adjustments, air in ballonets, fuel in tanks, etc. Variations in the shape are bound to occur due to changes in the above conditions and due to irregularities in the fabric. That these variations are slight, however, is proven by the very uniform appearance of all airships which have been built to standardized specifications. In the design of new ships it has been found better to err in getting the tail a little too high rather than too low, because there are always more ways of pulling it down than letting it up. In all this it should be remembered that the *height* of the tail and the *angle* of the tail are two different things, which must often be handled in different ways.

Flight License Compulsory

The Joint Army and Navy Board on Aeronautic Cognizance wishes to call attention to an occurrence of recent date, the seriousness of which must be apparent to every one.

On March 25, 1919, during the parade held in celebration of the home coming of the 27th Division in New York City, a flying boat was seen in flight directly up and down Fifth Avenue above the parade, at a dangerously low altitude estimated to be from three to five hundred feet, which was so low that in case of motor failure the pilot would have had no choice except to land in the crowd on the Avenue. He could not have reached even a fringe of Central Park owing to the number of trees.

Inquiry has developed that this boat was piloted by a civilian who was flying without the license required by the Proclamation of the President of the United States on February 28, 1918. This proclamation provides that a license must be obtained from the Joint Army and Navy Board on Aeronautic Cognizance by or in behalf of any person who contemplates flying in a balloon, airplane, seaplane, or other machine or device over the whole United States, its Territorial Waters, Insular Possessions, and the Panama Canal Zone. Heavy penalty is attached to violation of this regulation.

There is no way of adequately providing for the public safety where airplanes fly at too low an altitude over cities or large assemblies of people. In case of accident a pilot would be forced to descend immediately, and human life and property would be endangered to a serious degree. All persons operating civilian aircraft are cautioned against the repetition of an occurrence such as the one which took place in New York on March 25, and are warned that before engaging in the operation of any airplanes or balloons, they must first secure a license from the Joint Army and Navy Board on Aeronautic Cognizance.

Chart for Performance Computations

By Richard I. Elliott

Wind tunnel experiments have given us very complete data on the lift and drag of a wing of given section and aspect ratio. These lift data must then be corrected for the particular design in order to allow for biplane interference, aspect ratio, wing-end form, and model ratio. The drift data must be corrected to allow for the parasite resistance of the structure. The simplest method of procedure is to combine all these corrections at one time on the polar diagram of the wing section as given by the wind tunnel data, and to derive from this revised or as close an estimate on the parasite resistance of the machine as possible, reduced to speed of 1 mile/hr., and further reduced to unit area by dividing by the wing area, for instance, if the parasite resistance of a machine traveling at rate of 60 m.p.h. and having 300 sq. ft. area is 150 lb. then

$$\frac{150}{60 \times 60 \times 300} = .000139 = K_p/A$$

whereupon, determine the machine-lift factors ψ which are

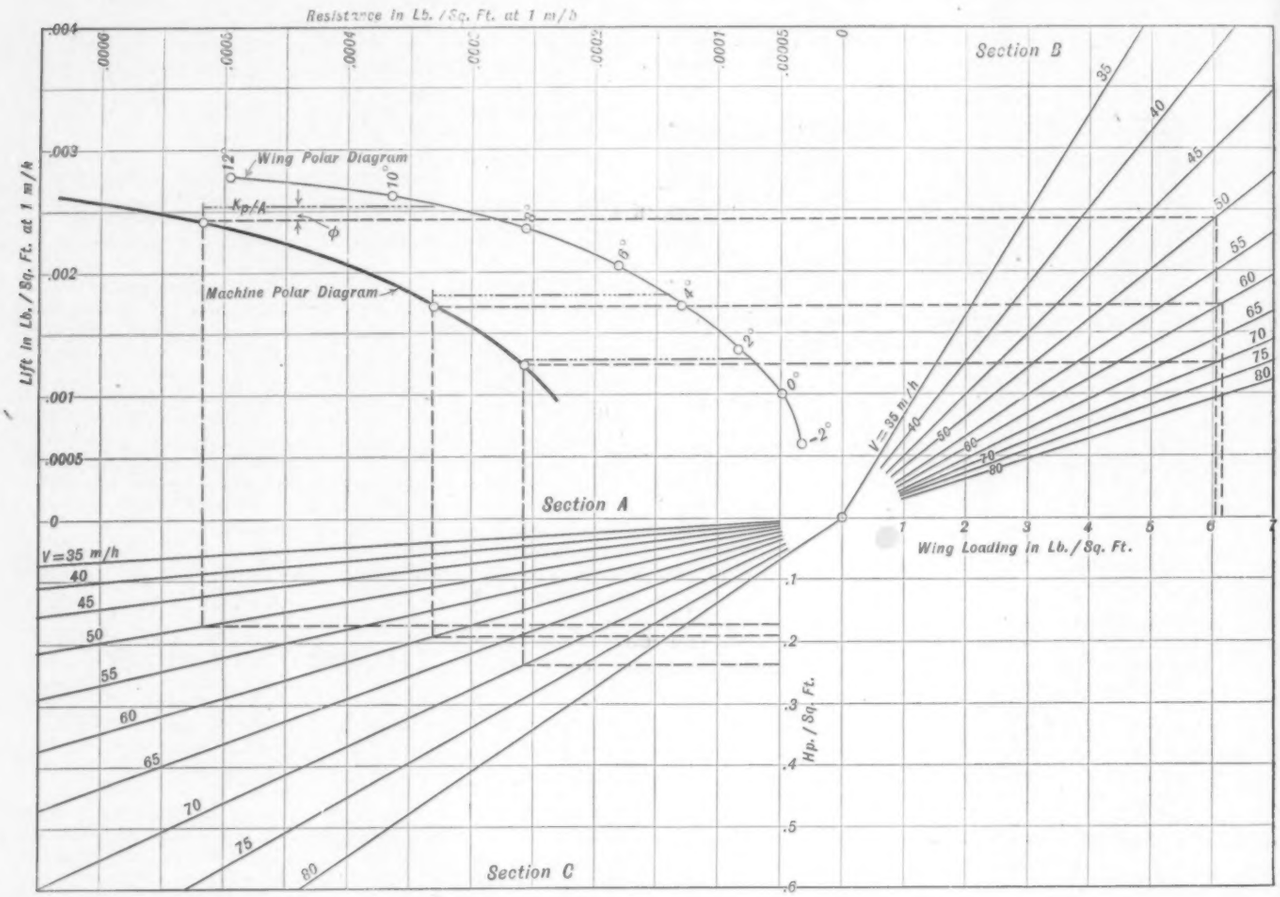
Resistance in Lb. / Sq. Ft. at 1 m/h
Section B
Wing Polar Diagram
Machine Polar Diagram
Kp/A
Lift in Lb. / Sq. Ft. at 1 m/h
Section A
Wing Loading in Lb. / Sq. Ft.
Hp. / Sq. Ft.
Section C
V=35 m/h

CHART FOR AIRPLANE PERFORMANCE COMPUTATIONS

machine polar diagram the characteristics of the machine as shown in the lower performance diagram.

The accompanying graph sheet has been prepared for the purpose of solving the equations graphically and consists of a central section A, in which the simultaneous lift and drift values (K_y and K_x) are plotted in the familiar polar diagram of Eiffel. As is well known, these values may be made to any of several sets of units as, for instance, lb./sq. ft. at 1 m.p.h., or lb./sq. ft. at 1 ft. per sec.; the former units are used in this article. The right-hand section B consists of radiating velocity lines drawn to a horizontal proportion of the square of the indicated velocities and having vertical lines representing the loading of the wing surfaces in lb./sq. ft. The left-hand lower section C also consists of radiating velocity lines drawn to a vertical proportion of the cubes of the indicated velocities, and having horizontal lines representing air-horsepower-required per sq. ft.

This graph sheet should be used in the preparation of the performance curves of the machine in the following manner: First plot in section A the polar curve for the particular wing section, marking thereon the angles of incidence; next prepare the compounds of the various factors affecting the lift, such as wing interference, aspect, wing end form, and model ratios, at each angle of incidence. These factors ψ will be in the form of a percentage and not a fixed amount and must be figured for each point desired. We are now ready to plot the revised or machine-polar diagram by extending the K_x readings toward the left a fixed amount corresponding with the value of K_p/A, as above determined, and by then shifting the point thus found either up or down an amount corresponding with the value of ψ for that angle of incidence as above found.

Now, since we know the value of the wing loading (W/A), we draw a line in section B vertically at the said point, to cut the radial velocity lines: from the intersection of each said velocity lines with said vertical line, draw horizontal lines to section A to cut the revised polar diagram, and then from the points thus obtained draw vertical lines to cut the corresponding velocity lines in section C and read off on the scale the hp./sq. ft. required for that velocity, which figures may be multiplied by the wing area to give the actual air-horsepower-required. These figures are then plotted and form the usual lower performance curve of the machine.

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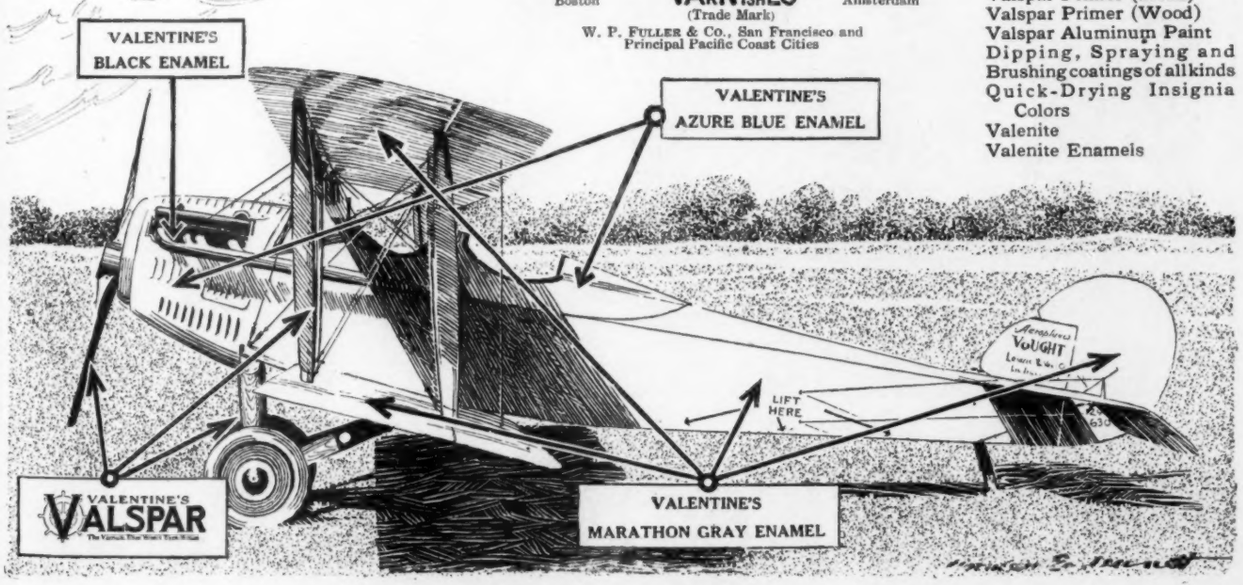

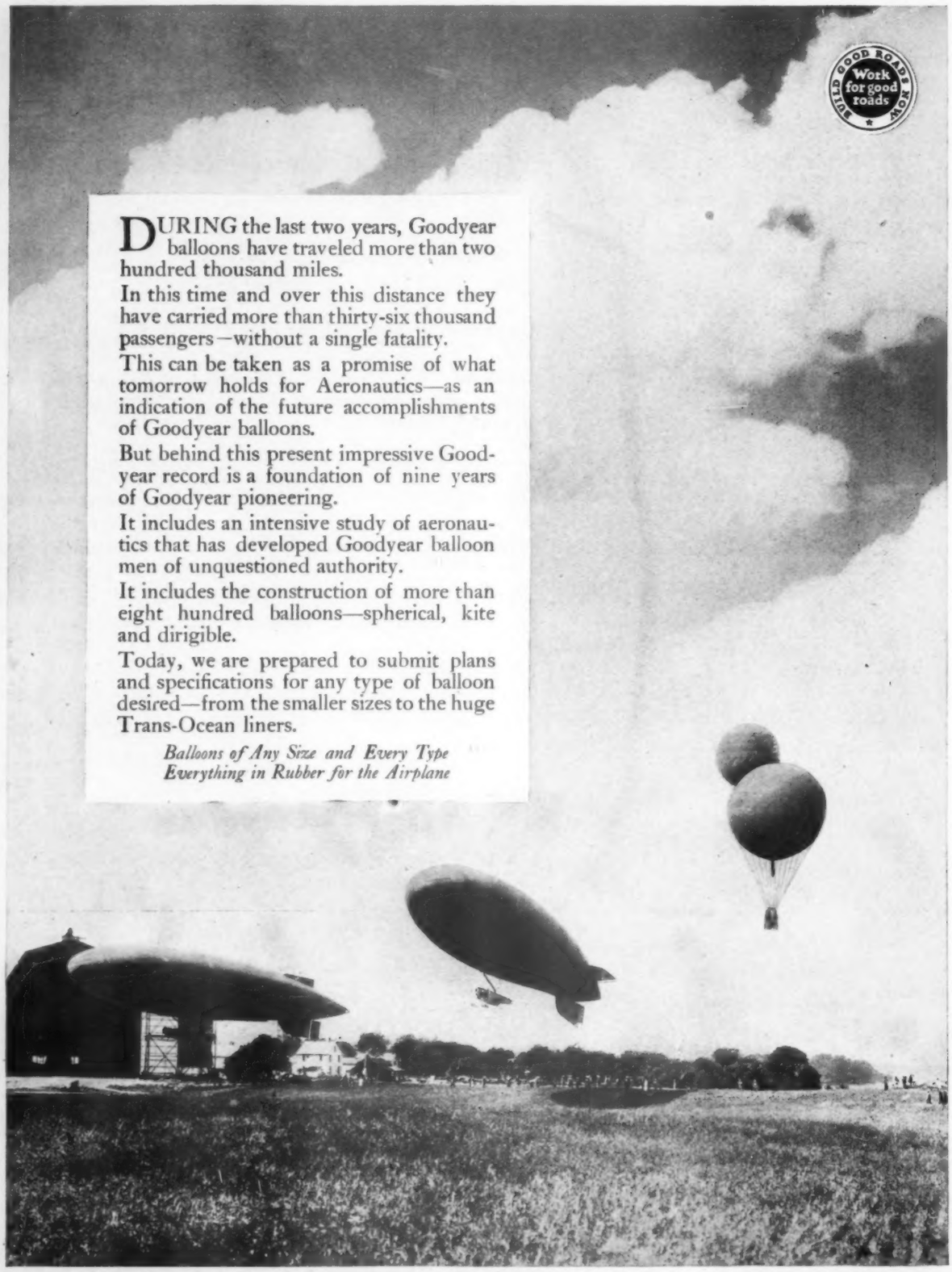

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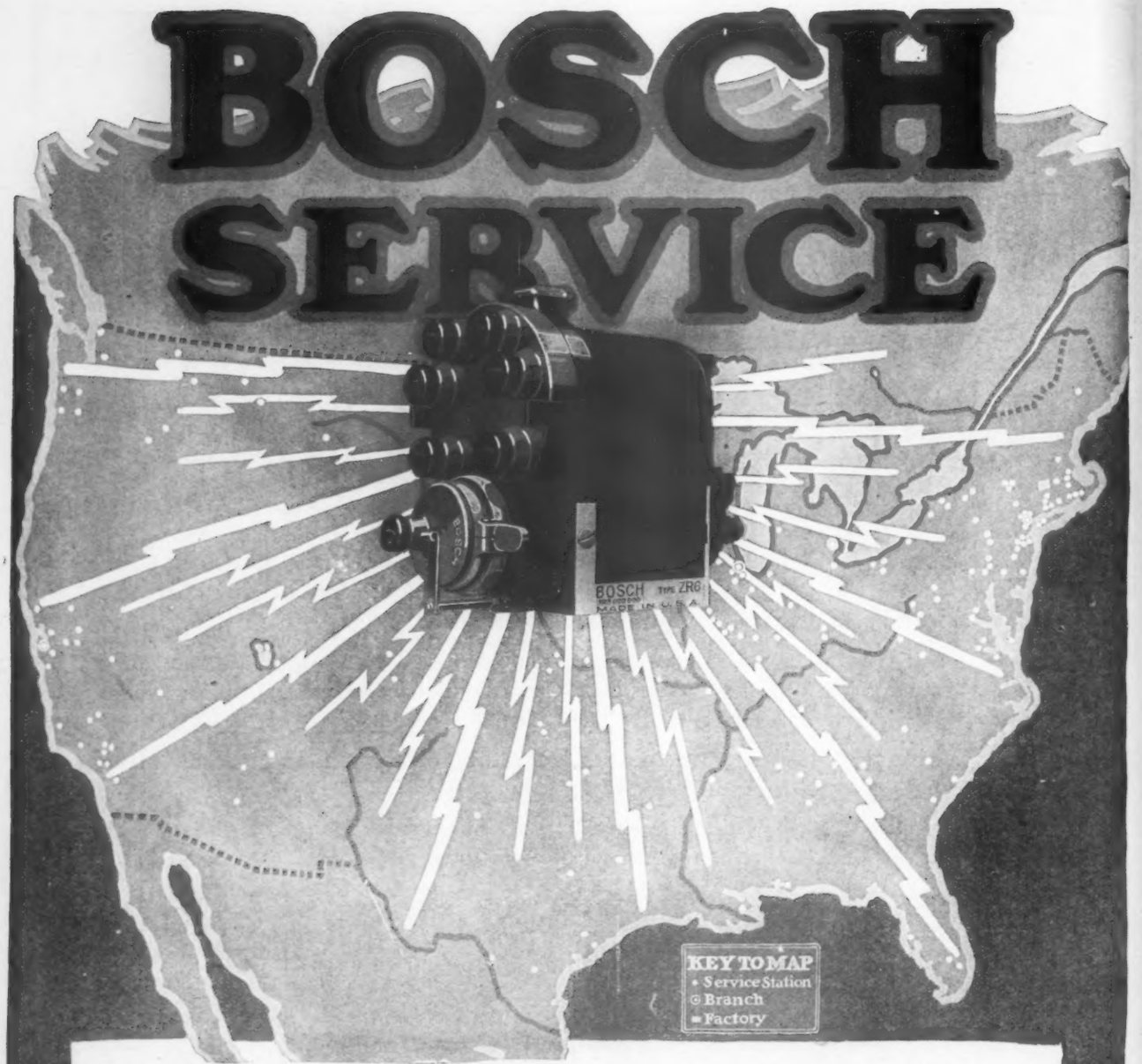

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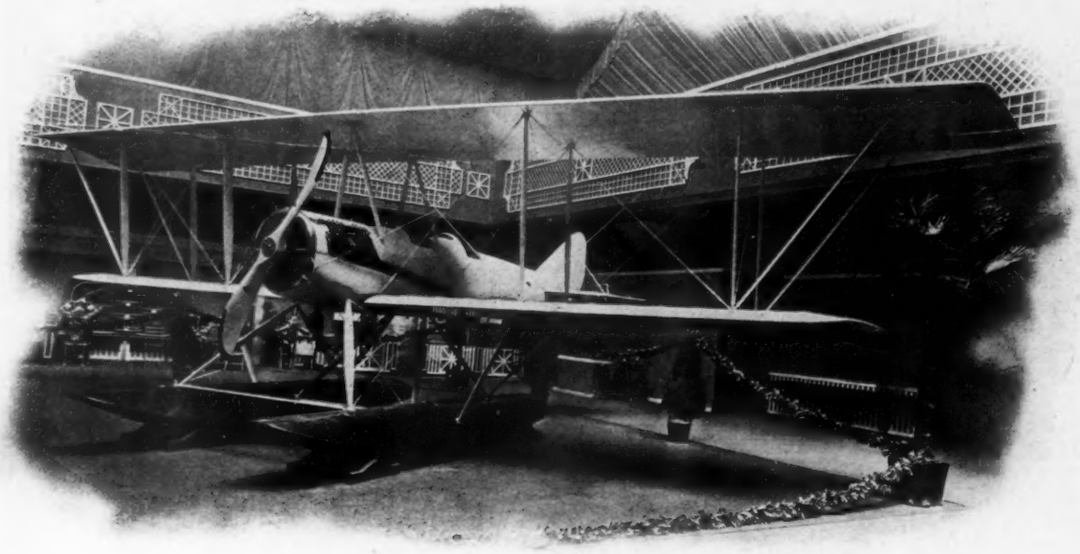

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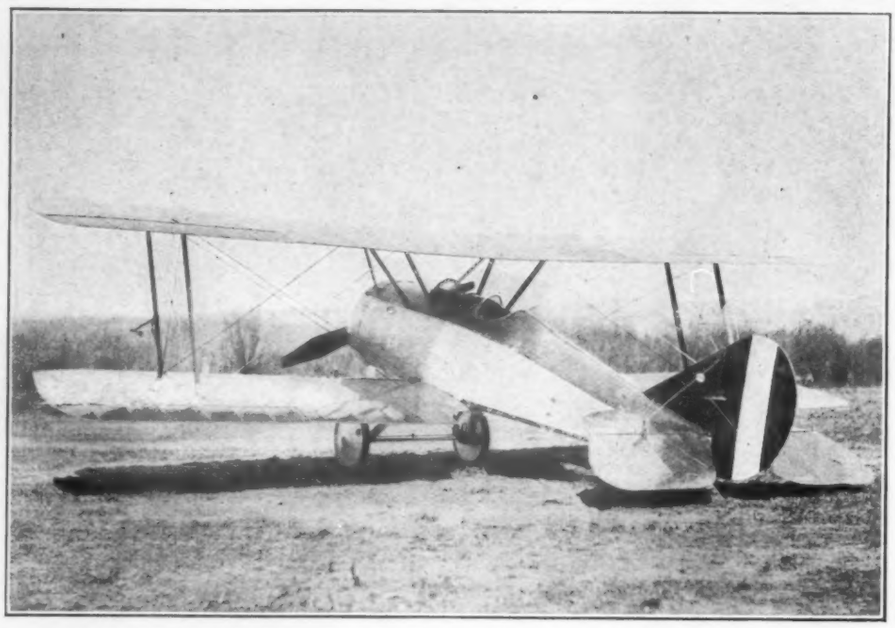

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More recently, the heir to the British throne flew over the battle lines in France, and yesterday, LOOPED THE LOOP IN AN AIRPLANE OVER THE HEART OF LONDON. We may assume that flying is fairly safe when the future hope of the British Empire indulges in aerial acrobatics. The Countess of Drogheda is presently giving flying exhibitions in aid of the British Red Cross. Premier Lloyd George frequently flew between London and Paris to attend the Peace Conference, as did Bonar Law, who owns an aero-limousine. King Albert of Belgium asserts it is safer "Up there" than "Down here". Other instances may be quoted.

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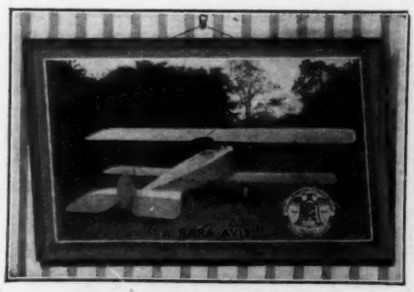

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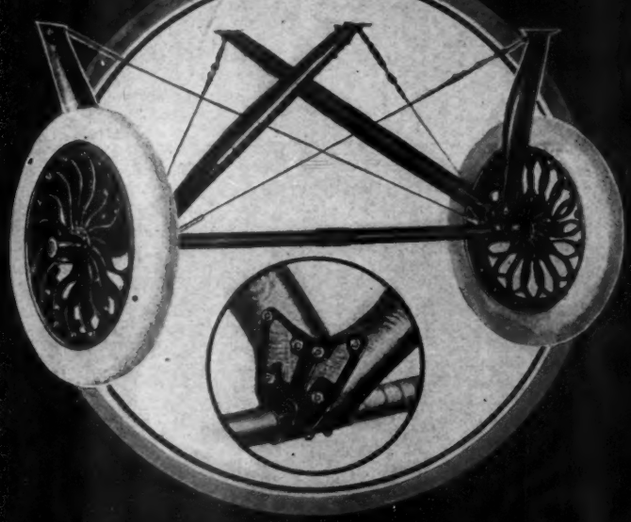

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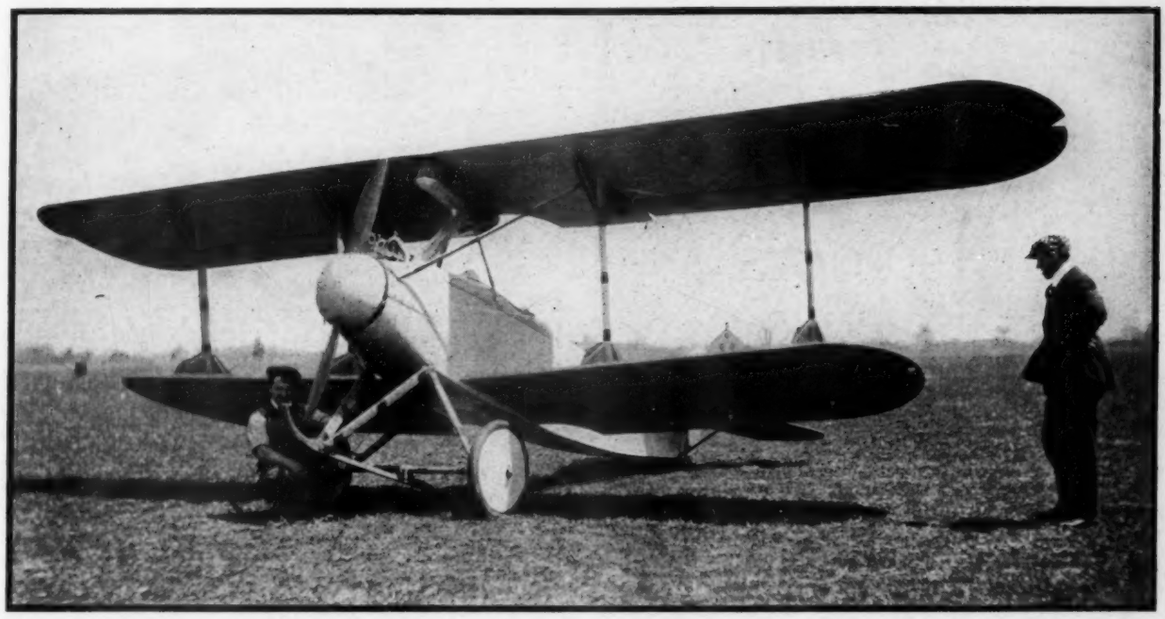

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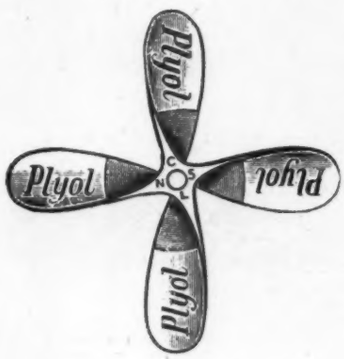

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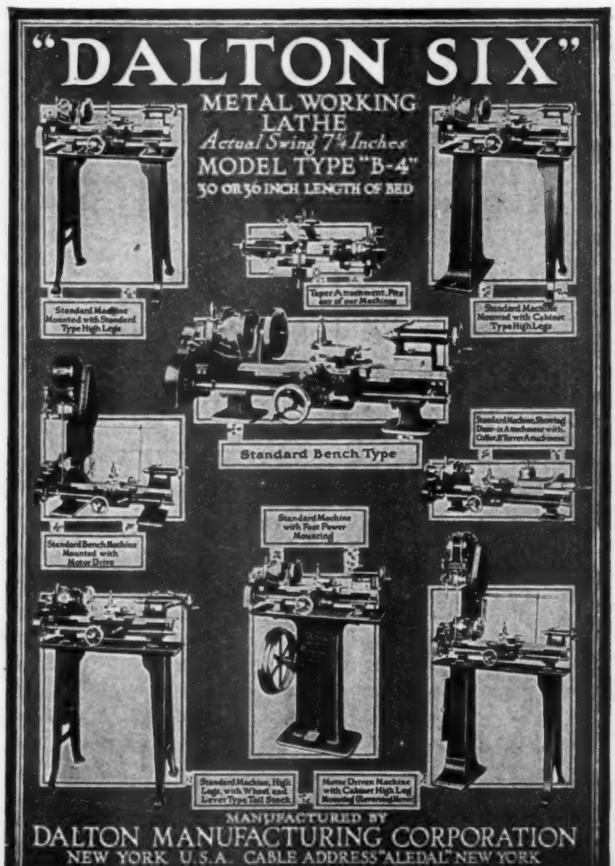

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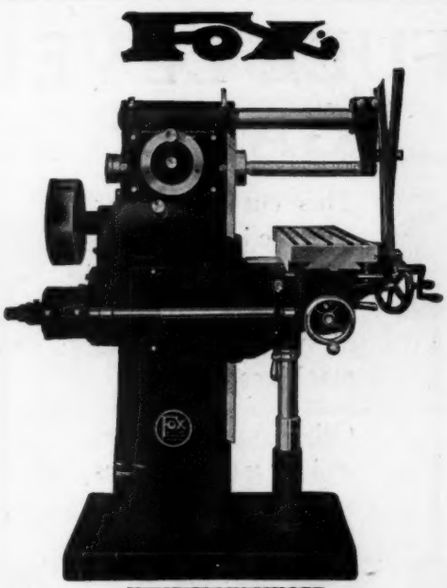

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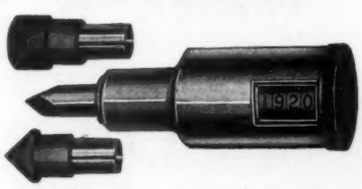

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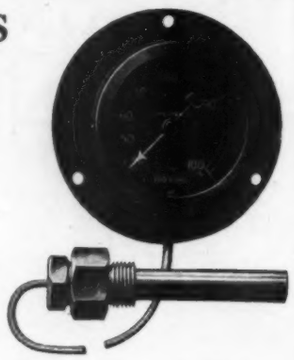

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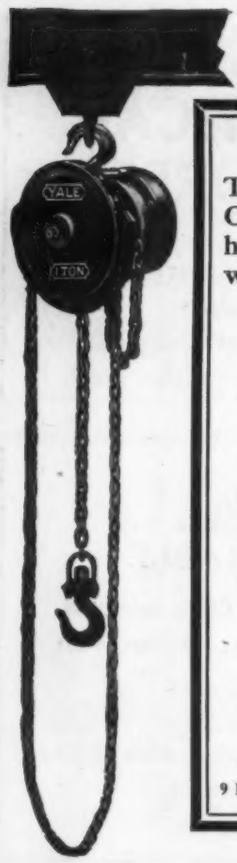

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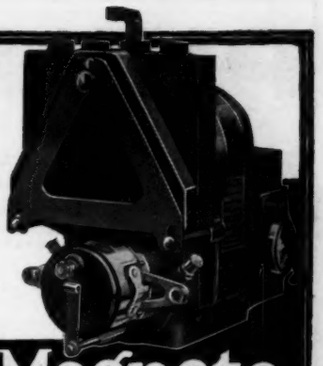

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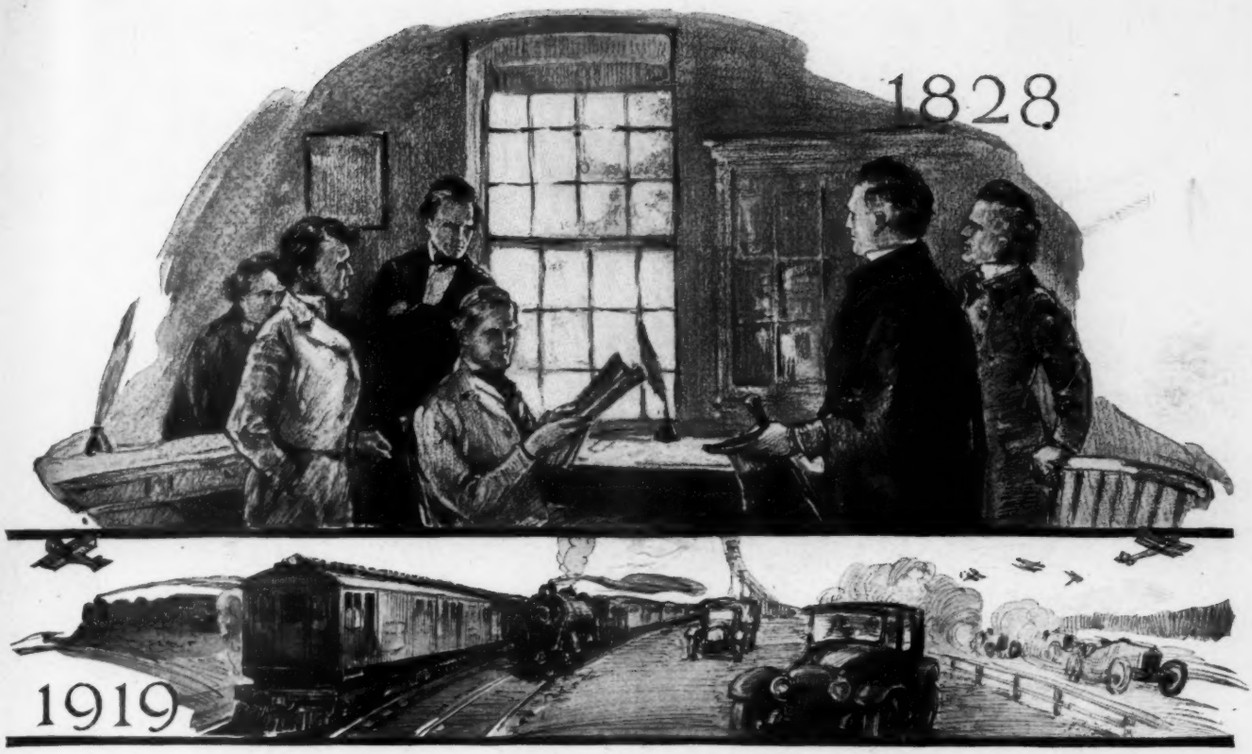

THEN AND NOW

IN 1828, in an Ohio town, a club of young men met to discuss the value and feasibility of steam railroads then in an incipient stage.

They desired the schoolhouse for their debates. That the school board considered this an innovation bordering upon sacrilege is indicated by its reply.

"You are welcome to the schoolhouse to debate all proper questions, but such things as railroads are impossibilities and rank infidelity. If God had designed that His intelligent creatures should travel at the *frightful speed of fifteen miles an hour*, by steam, He would clearly have foretold it through His holy prophets. It is a device of Satan to lead immortal souls down to hell."

What would this school board say had they lived now—when such "frightful speeds" as 90 miles per hour are attained on the railroads and 160 miles per hour by airplanes?

Such extreme speeds are made possible through the use of silent, smooth ball bearings—of that high degree of efficiency found in *Gurney Ball Bearings*—which eliminate most all friction and stand the acid test of severest service.

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